METALLURGIA

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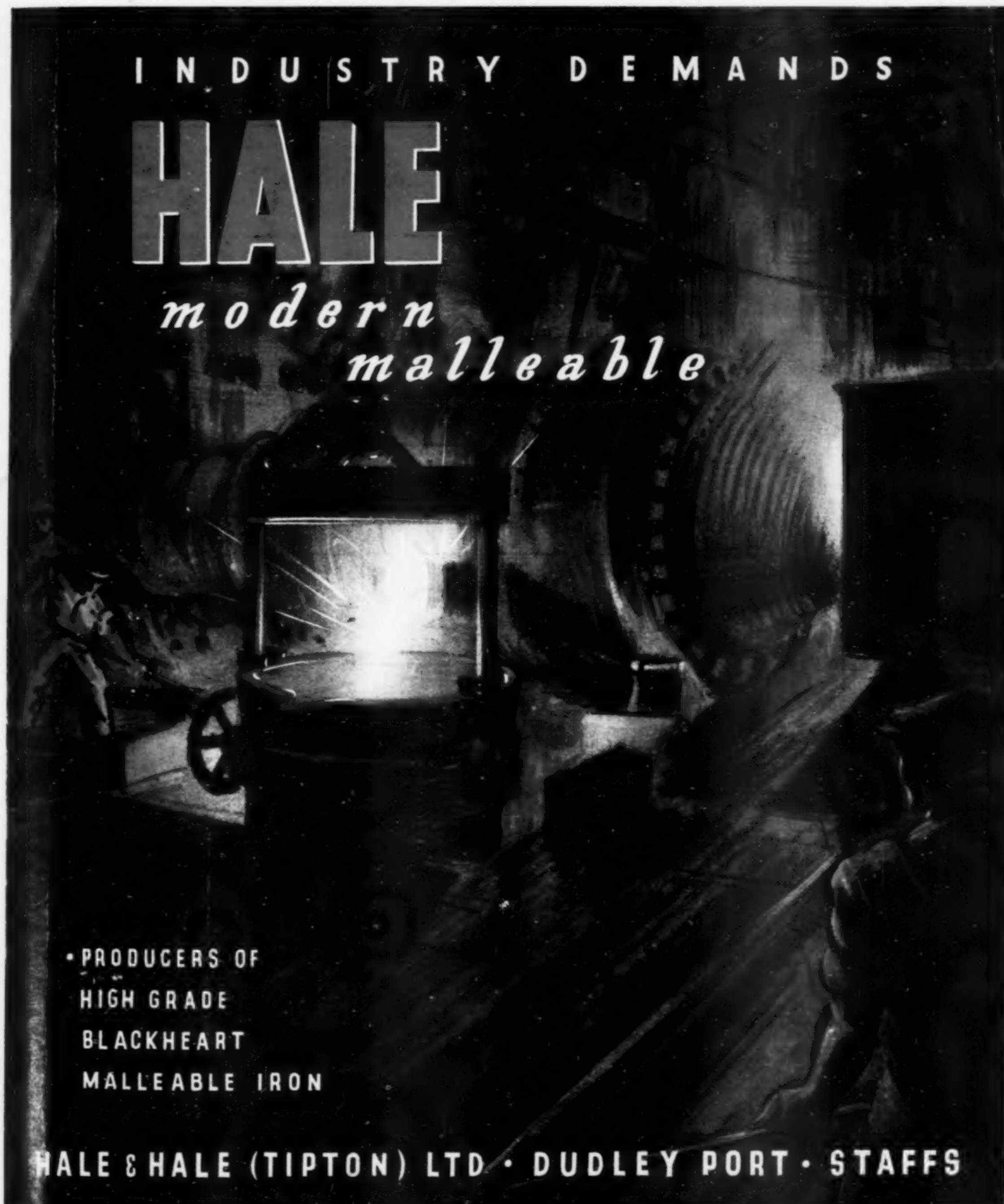

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THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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FEBRUARY, 1952 Vol. XLV No. 268

Technical Society Support

IN presiding over a recent meeting of the Manchester Metallurgical Society, held jointly with the Iron and Steel Institute, the Guest Chairman, Mr. J. Sinclair Kerr commented on the fact that many technical societies abroad receive considerably greater support than do their British counterparts. In particular, he mentioned that, whereas we feel we have a full house with an attendance of 400 at one of our national metallurgical meetings, he had attended similar meetings on the Continent where the number participating had been several times that figure. One hears too of the almost astronomical figures of membership of such a body as the American Society for Metals, figures which, even allowing for the larger population and the greater attention paid to technology, are still relatively high.

WE mourn the passing of our beloved King, George VI, by whose untimely death the British Commonwealth of Nations has suffered a grievous loss. Coming to the throne in peculiarly difficult circumstances, he maintained throughout his reign the highest traditions of a constitutional monarchy. By his courage and fortitude in the face of danger and adversity, by his steadfastness of purpose and, above all, by his devotion to duty, he set a shining example to his people, whether in the dark days of war or in the no less difficult years of peace which followed.

The mantle of sovereignty has now fallen on the youthful shoulders of his daughter, Queen Elizabeth II, who has already shown herself to be possessed of that same regard for tradition and devotion to duty as characterised her father. May her reign be long and happy.

This is a matter of fundamental importance to metallurgists throughout the country for, as was pointed out by Mr. R. Chadwick in his Chairman's Address to the Birmingham Local Section of the Institute of Metals last April, the status of a profession is influenced in no small measure by the efficiency of its professional organisation and the quality of its official publications. Mr. Chadwick went on to point out that the Institute of Metals and the Iron and Steel Institute have achieved a world standing second to none as publishing bodies for metallurgical research, whilst the Institution of Metallurgists, which represents the unified professional interests of both ferrous and non-ferrous metallurgists, is already sufficiently representative to make its opinion felt in the field of metallurgical education and training. To both publishing and professional bodies, however, the support of every practising metallurgist is essential if they are to carry out in an efficient manner the work for which they were created. The older, more highly organised bodies, derive great strength from a large professional membership and if equal loyalty were to be accorded in the metallurgical sphere it would be a powerful factor in raising the profession to a comparable status.

Granted that a case has been made out for all-out support of the various metallurgical organisations, it is necessary to be quite clear as to what constitutes support—mere membership, or active participation in meetings. In this connection, it is worthy of note that although a figure of 300–400 may be regarded as satisfactory for a national meeting of the Iron and Steel Institute or the Institute of Metals, the respective memberships are of the order of 5,000 and 3,000. Such figures cannot be regarded as completely satisfactory, however, so long as there are some outside the organisations who could, with advantage to themselves and their colleagues, be within them. This is perhaps of greatest importance in the case of the Institution of Metallurgists, where the larger the membership, subject to the maintenance of sufficiently high standards, the more efficiently will it be able to carry out its task of raising the status of the metallurgical profession.

The membership figures for each of these bodies are increasing, but in view of the continually rising cost of living, the subscription rates are probably responsible for the rate of increase being less than it might be. In the case of certain other professional bodies, membership of, and maintenance of subscriptions to, the registering institution is necessary for the continuance of professional status and the right to practise. This has the advantage that the annual subscriptions are admitted for relief of income tax, unlike the optional subscriptions to the metallurgical bodies. It has always seemed unfair that money spent on membership of technical and professional bodies should not be regarded as necessary expenditure, in the same way as is that incurred by a workman in the purchase of his tools. A comprehensive membership would add weight to any claim for exemption. While there is evidence of the adverse effect of the cost of membership it is a little difficult to see just what can be done about it in view of the enormous increase in the cost of paper and printing, which represents a substantial proportion of the expenditure.

In considering the question of attendance at the technical sessions of the meetings of the publishing institutes, it should be remembered that this involves absence from the office, laboratory or workshop for two or three days in the case of members living far from the place of meeting, and this is not always expedient. Furthermore, for the benefit of members, it is customary to arrange for the presentation at one session of papers likely to appeal to a particular section of the membership and this leads to some of the meetings appearing to be less representative of the membership than is actually the case. Nevertheless there are very real benefits to be obtained from an exchange of views on technical

matters—whether made publicly or privately—such as is possible at such meetings, and on those grounds alone there is much to be said for active participation.

Turning from the national to the local scene, the circumstances are completely different: neither subscription rates nor loss of working time can be advanced as reasons for the fact that membership and attendances are appreciably below the maximum possible. Is it then indifference? Much has been said and written recently in defence of the scientist against the suggestion that he is oblivious to all but science, and it has been pointed out that his tastes are probably far more catholic than those of the arts man, who very seldom gives a thought to scientific matters. It seems strange, therefore, that when one comes to technical matters, there seems to be a tendency for the scientist to restrict himself to his own particular line. By their nature, local societies have to cater for a variety of members and the attendance at meetings usually consists of a hard core of regulars with the addition of a changing group of members attracted by the particular subject under discussion. This savours of specialisation carried to excess, and it is difficult to imagine anyone who would not benefit from a broadening of his technical background. In any case, the same type of problem may be encountered in widely different fields and the method used to deal with it may be capable of widespread adoption, so that from a practical point of view there is much to be said for more effective support of the local technical societies.

Finally we might ask ourselves whether it is just a coincidence that in the U.S.A., where the technical societies receive such strong support, technology receives greater attention, the technologist has a higher status, and productivity is higher.

Commonwealth Scientific Conference

Sir Ben Lockspeiser, K.C.B., F.R.S., Secretary of the Department of Scientific and Industrial Research, will lead the United Kingdom Delegation to the British Commonwealth Scientific Conference which is to be opened by the Prime Minister of Australia in Canberra on February 18th. With Sir Ben will be Sir William Slater, K.B.E., Secretary of the Agricultural Research Council, Dr. F. H. K. Green, representing the Medical Research Council, and Dr. Alexander King, Head of the Intelligence Division of the Department of Scientific and Industrial Research. All the self-governing countries of the Commonwealth will be represented by delegations, and colonial research will be represented by Dr. G. A. C. Herklots of the Colonial Office. The United States Government is also sending observers. After a few days in Canberra the delegates will be taken by road to Melbourne, where the Conference will resume until March 9th.

Active preparations for the Conference, whose main object is to further collaboration in research throughout the British Commonwealth, have been going on for the last 18 months under the auspices of the Standing Committee, set up by the 1946 Conference, which consists of the heads of the official research organisations throughout the Commonwealth. The Agenda has been prepared by a Working Party of their deputies, usually the scientific liaison officers of the various countries. The Chairman of the Conference will be Dr. Clunies Ross, Chairman of the Australian Commonwealth Scientific and Industrial Research Organisation.

The spreading of information and personal contacts between scientists is fundamental to all forms of collaboration in research, and the Conference will review the facilities and machinery for attaining these objectives and make general recommendations, where necessary, for improving the present arrangements. It will then proceed to examine a number of subjects which, after previous consultation between the various countries, have been suggested as possible topics for collaboration. Among industrial subjects now proposed for consideration are industrial microbiology, the utilisation of seaweed, research on metal casting, sulphur production, the utilisation and beneficiation of low-grade ores and wastes, research on wool fibre, soil mechanics, and the utilisation of solar energy by physical or biological means. Agricultural and medical subjects will also be considered by the Conference.

Another matter which will be considered is relations with international research organisations—both the U.N. Special Agencies such as UNESCO and FAO and with Western European Countries, members of the Organisation for European Economic Co-operation (OEEC). In this connection the Conference will derive great benefit from the presence of the U.S. observers, who are expected to include in their number Mr. J. W. Joyce, Deputy Scientific Adviser, U.S. Department of State.

Institution of Metallurgists
1952 Examinations

The next examinations for the Licentiateship, Associateship, and Fellowship of the Institution of Metallurgists will be held from 25th August to 2nd September, 1952, at various centres. Candidates must submit their applications for permission to enter the examinations before 1st May (1st April in the case of overseas applicants). Application forms and further particulars may be obtained from the Registrar-Secretary, The Institution of Metallurgists, 4, Grosvenor Gardens, London, S.W.1.

International Machine Tool Exhibition

Organised by the Machine Tool Trades Association of Great Britain, the International Machine Tool Exhibition, 1952, will be held at Olympia, London, from 17th September to 4th October, inclusive. The whole of the exhibition space available (on all floors of the Grand, Empire and National Halls), comprising some 250,000 sq. ft., has been let to exhibitors who will have on show machine tools, engineers' small tools, gauges, measuring equipment, testing equipment, presses and hammers, heat treatment plant and woodworking machinery. Apart from Great Britain, exhibits will be shown from leading machine tool manufacturing countries, including the U.S.A., France, Germany, the Scandinavian countries, Holland and Italy.

Non-Ferrous Metals in Western Europe

FROM buttons to building materials, from costume jewellery to the machinery that runs the exhibits at "fun fairs," hundreds of domestic items containing non-ferrous metals have either been placed on Western Europe's list of prohibited goods, or will be in the near future.

Even in pre-war days, Western Europe's consumption exceeded production of such non-ferrous metals as aluminium, copper, zinc, lead, nickel and tin. To-day, the expanding manufacture of defensive armaments and the stock-piling of these strategic materials increases the demand. Shortages have become critical, and necessitate a large import programme and the reduction of domestic consumption. The Organisation for European Economic Co-operation, consisting of delegates from 18 Marshall Plan countries, has taken action by compiling several common lists of articles to be banned for civilian use: enforcement of the ban has been left to member countries.

Greek workmen move tram loads of raw bauxite ore to the end of the Eleusis pier where it will be loaded onto the Yugoslav ship "Kosmaj" for shipment to Germany.

The Katanga region of the Belgian Congo has rich deposits of copper and zinc. These smelting and refining works have been set up at Lubumbashi, near Elisabethville, by the Union Miniere du Haut Katanga.

Copper and copper alloys have been excluded since last October from the manufacture of 264 different products. These range from window frames to cocktail shakers, and include hardware, electrical appliances, transportation and refrigeration equipment, jewellery, gifts and novelties. Nickel and zinc articles face a similar fate. In the United Kingdom, 287 zinc articles have been banned from civilian markets and the O.E.E.C. is now studying the list in relation to member countries, to whom 488 nickel items have been submitted for banning. Other cuts are also to be considered.

Shortages occurring in the immediate post-war years and since have been greatly reduced through Marshall Plan aid. From the beginning of the programme, in 1948, until the end of 1951, $606,600,000 was made available for payment of imports. Using these funds, shipments of non-ferrous metals from Canada totalled $308,000,000; from the U.S.A., $139,100,000; Latin America, $119,000,000; Marshall Plan countries, $34,000,000; and other countries, $5,700,000.

Meanwhile, attempts to increase production were inaugurated both at the mining and smelting levels and for this additional E.C.A. dollar grants were made, together with the provision of technical assistance and purchase contracts. Although results show a sizeable increase over pre-war averages, consumption has also increased, leaving an estimated deficit of 20% for 1951.

Copper requirements for 1951 exceeded the available supply by about 289,000 metric tons, but this deficit is expected to be reduced by conservation methods, and attempts are being made, through E.C.A. assistance, to increase production at the mines. The largest producers of copper and its products are the United States, Chile

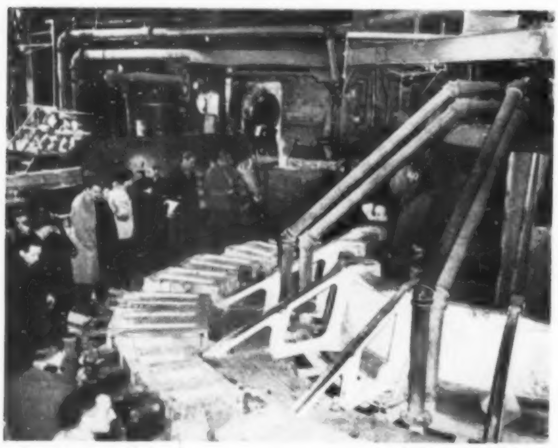
View of the Turkish copper mines at Ergani in Central Anatolia. They are among the world's richest, their reserves of high grade ore being estimated at a million tons.

This native miner is employed in prospecting for copper and manganese at Bon Kais, 60 kilometres from Colomb Bechar, Algeria.

and the Belgian Congo. Consumption of copper in Western Europe in the period 1952–53 is estimated at 1,174,000 metric tons.

Zinc presents the most critical shortage after copper, with an estimated deficit for 1951 of 100,000 tons. This will have to be made up by imports from the non-participating sterling area. The largest suppliers of zinc are the United States, Chile and Morocco, and in the programme for expanding zinc production there is a conflict between the desire to conserve resources and the demand to boost production of the ores. Output is continuing to expand, however, as development projects in Morocco move toward full production. In addition, Italian plans now being studied will, if put into operation, expand production by an estimated 90,000 tons a year in each of its two mining areas.

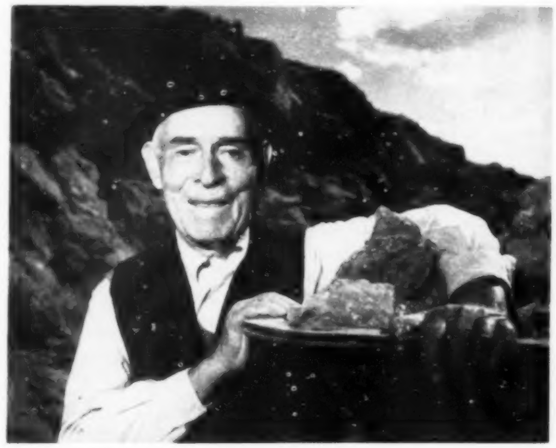
Aluminium is in short supply in the United States, but in Western Europe the situation is somewhat



Members of a Technical Assistance Team from the French non-ferrous metals industry watch the operation of an automatic casting machine at the American Metals Company plant at Carteret, New Jersey.

better. The greatest bottleneck over here, however, is the enormous electric power needed for the extraction of aluminium, and it has been estimated that with more power the output of the metal could be raised by 5–10%. For this reason, steps are being taken to expand power capacity in various production plants, either by diverting power from less important operations or by starting new power stations. In 1950, Western Europe produced some 230,000 metric tons of aluminium, imported 240,000 tons, consumed some 400,000 tons, and exported the difference. France's share of this production was 70,000 metric tons, and when new hydroelectric projects open in the country, especially those along the Rhone River, the added electric power is expected to increase production considerably, although it is doubtful whether the target capacity of 110,000 metric tons a year can be reached quickly.

In contrast with other metals, tin production in Western Europe has fallen by 34,000 tons since the 1935–38 period, while the price has risen rapidly. In



Ancient silver, lead and zinc mines are being revitalised. This 80-year-old Greek foreman still remembers the old mining sites and is happy about their re-opening.

consequence of the price rise of 86% between June and December, 1950, the United States stopped buying for the stockpile and the supply is, therefore, larger than would be the case with a lower price. In 1950, the Western European nations produced 113,000 metric tons of tin, imported 20,000 tons, exported 78,000 tons and consumed the remainder.

Lead production in 1950 reached some 336,000 metric tons, another 300,000 tons was imported, and a total of 523,000 tons consumed. The corresponding figures for nickel were 36,000, 14,000 and 33,000 tons.

While the gap between non-ferrous metal production and consumption is expected to continue, the scarcity has not been as severe as was expected following the outbreak of the Korean war. Meanwhile, the non-ferrous metals industry and Marshall Plan officials are continuing their studies of the situation in an effort to relieve the hardship on domestic economies, and at the same time make sure the strategic metals are channelled to areas where they are most needed.

The Effect of Stirring on the Rate of Desulphurising Carbon-Saturated Molten Iron with CaO-SiO_2-Al_2O_3 Slags

By C. E. A. Shanahan, B.Sc., F.R.I.C.
Steelmaking Division of the British Iron and Steel Research Association

The present raw material situation in the iron and steel industry is emphasizing the importance of efficient methods for metalloid removal. In this note, the author presents experimental evidence to show the beneficial effects of stirring on the desulphurisation of molten iron with CaO-SiO_2-Al_2O_3 slags.

THE present shortage of scrap, coupled with the deterioration of iron ore quality, will result in larger quantities of deleterious elements such as phosphorus, silicon and sulphur being associated with each ton of steel made. This has intensified the interest in efficient methods for metalloid removal.

Sulphur is a particularly troublesome element to remove, especially in the basic open-hearth furnace, and attention is, therefore, being directed at possible means for its elimination from blast furnace metal before the latter is charged to the open-hearth furnace. Initial experiments have been performed on the rate of desulphurisation of carbon-saturated molten iron by CaO-SiO_2.Al_2O_3 slags of the blast-furnace type at a temperature of approximately 1,430° C. As expected from theory, and the practical work of Lo-Ching Chang and Goldman,[1] and of Derge, Philbrook and Goldman,[2] a marked increase in desulphurisation rate is obtained by stirring the slag and metal together. Although the experiments are by no means complete, it is thought that a brief statement of the technique used and the results already obtained would be valuable if only to emphasise the possible advantages obtained by the intimate mixing of slag and metal.

Experimental Method

The melting was performed in a carbon crucible ($2\frac{1}{4}$ in. i.d. $\times$ 2 in. deep, wall thickness $\frac{1}{4}$ in.) which was heated by an indirect carbon arc approximately $1\frac{1}{4}$ in. above the top of the melt. A carbon sheath (wall thickness $\frac{3}{32}$ in.) was positioned horizontally through a hole in the side of the crucible, so that the tip was completely immersed in the melt and held in place by packing the space between the hole and sheath with alumina cement. Temperature readings were obtained with an alumina-sheathed Pt/Pt-13% Rh. thermocouple placed within the carbon sheath. In order to agitate the system, a carbon paddle was immersed in the melt at an angle of approximately 45° to the horizontal and rotated at approximately 500 r.p.m. The paddle was made by cutting holes and a spiral at the end of a $\frac{5}{8}$ in. diameter carbon electrode—a similar design to that employed by Hatch and Chipman.[3]

No slag-metal stirring was employed for the first melt.

TABLE I.—EXPERIMENT 1 (NO STIRRING)

Time (mins.)	Sulphur in Metal %	Sulphur in Slag %
0	0·230	0
17	0·169	0·179
32	0·139	0·209
62	0·120	0·245
92	0·101	0·314
122	0·090	0·316

TABLE II.—EXPERIMENT 2 (STIRRING)

Time (mins.)	Sulphur in Metal %	Sulphur in Slag %
0	0·207	0
21	0·142	0·203
36	0·079	0·446
51	0·056	0·506
66	0·044	0·577
96	0·029	0·585

TABLE III.—EXPERIMENT 3 (STIRRING)

Time (mins.)	Sulphur in Metal %	Sulphur in Slag %
0	0·219	0
26	0·114	0·315
44	0·069	0·436
61	0·048	0·497
78	0·038	0·527
96	0·035	0·529
126	0·013	0·623
141	0·010	0·613

TABLE IV.—SLAG ANALYSES

Sample	CaO%	SiO_2%	Al_2O_3%	Total Fe%
Initial pre-fused	39·6	37·0	21·0	0·04
Final slag, Expt. 1 ..	38·2	37·0	23·5	0·08
Final slag, Expt. 2 ..	39·1	36·2	22·8	0·03
Final slag, Expt. 3 ..	40·9	32·6	24·3	0·05

Approximately 170 g. of Armco iron were melted in the carbon crucible and 1·3 g. of crushed lump ferrous sulphide added. Heating was continued for 30 minutes and after stirring with a carbon rod to ensure even distribution of carbon and sulphur a small sample of the metal (approximately 1 g.) was obtained with a fused silica tube and a rubber suction bulb. Approximately 60 g. of the pre-fused and crushed slag were introduced and, when melted, a pair of slag and metal samples obtained. It was found that slag samples were best taken with a $\frac{3}{16}$ in. diameter brass rod, and both the slag and metal sample weights were always kept to a minimum. At various intervals throughout the heat, pairs of slag and metal samples were obtained. Table I lists the sulphur contents of the latter which were obtained by combusting the crushed samples in oxygen and determining the sulphur dioxide evolved.

1 Lo-Ching Chang and Goldman, K. M. A.I.M.M.E. T.P. No. 2367, Class C. *Metals Technology*, June, 1948.
2 Derge, G., Philbrook, W. O. and Goldman, K. M. *Trans. A.I.M.M.E.* **188**. Sept., 1950, p. 1111.
3 Hatch, G. G. and Chipman, J. *Metals Trans.*, April, 1949, p. 274.

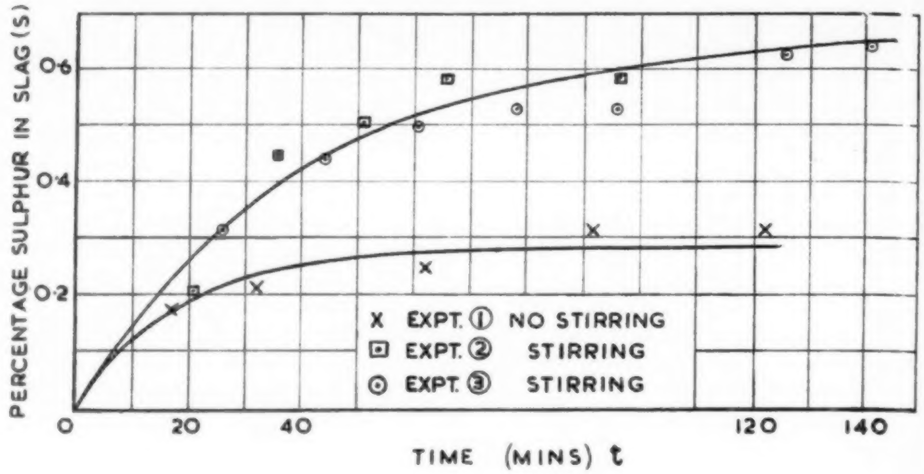


Fig. 1 (s)/t curves for the three sulphur transfer experiments Temperature ca 1430° C.

Two experiments have been performed using the rotating carbon paddle. The technique was similar to that described above, except, of course, for the use of the paddle which was kept continuously rotating at 500 r.p.m. throughout the heats. Tables II and III list the sulphur contents of the slag-metal samples.

Fig. 1 illustrates the marked increase in the rate of sulphur removal from the metal accompanying the use of the paddle, and suggests that the use of stirring devices in ladle refining operations might be advantageous in many cases.

The analysis of the pre-fused slag used throughout the experiments is given in Table IV. Also included are the analyses of the final slags remaining over the metal at the conclusion of the melts. It will be seen that in the stirred melts (experiments 2 and 3) which terminated nearer to equilibrium conditions, marked silica reduction from the slag occurred. The final metal from experiments 2 and 3 contained approximately 1 and 2% silicon, respectively.

Discussion of Results

There is appreciable evidence to show that most metallurgical chemical reactions are extremely rapid at steel-making temperatures. The estimated energies of activation[4] associated with such reactions, coupled with the apparent slowness of many of them, suggest that it is the rate at which the reactants are brought together or the products taken away that determines the overall speed. In other words, the reactions appear to be diffusion controlled. Very practical evidence of this is obtained in the Bessemer converter where the refining reactions are very much quicker than those of the open hearth, mainly as a consequence of the breaking down by agitation of the very low concentration gradients arising from slow diffusion reactions. Further evidence is obtained from the Perrin process which, as is well known, can dephosphorise and desulphurise molten steel almost instantaneously due to the violent slag-metal agitation that occurs. Measurements by Derge, Philbrook and Goldman,[2] and by Holbrook, Furnas and Joseph,[5] of the diffusivity of sulphur in liquid slags and iron, show that diffusion is extremely slow.

That diffusion is controlling the rate of desulphurisation in the above experiments is shown by the beneficial effect of stirring. Experimental evidence has been provided by Derge, Philbrook and Goldman[2] to show that the mechanism of desulphurisation with CaO-SiO_2-Al_2O_3 slags involves the following consecutive reactions:

$$[FeS] \rightleftharpoons (FeS) \quad \ldots\ldots\ldots\ldots \quad (i)$$
$$(FeS) + (CaO) \rightleftharpoons (CaS) + (FeO) \quad \ldots\ldots \quad (ii)$$
$$(FeO) + C \rightleftharpoons [Fe] + CO\,(gas) \ldots\ldots \quad (iii)$$

where the square and round brackets denote the metal and slag phase, respectively.

The curves drawn through the experimental points in Fig. 1 are exponential in form, and a simple relationship exists between the percentage of sulphur in the slag and that in the metal, since conditions within the arc furnace were so reducing that no appreciable sulphur loss occurred to the gas phase (as judged by a sulphur balance, making due allowances for the very small weights of samples withdrawn during the heats). Thus the experiments to date adequately support the equation :—

$$\frac{d\,(S)}{d\,t} = k_1\,[S] - k_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (iv)$$

where k_1, k_2 are constants; t is the time in minutes (S) and [S] are the percentage of sulphur in the slag and metal, respectively.

For the stirred melts, k_2 is negligibly small, and equation (iv) is formally Fick's first law of diffusion for a thin tenacious metal film of constant thickness and area existing between the metal and slag, wherein the FeS concentration linearly drops to a very low negligible value. This is a very similar picture to that described by Darken[6] for carbon oxidation by slag or ore in the open-hearth furnace. Thus, a possible explanation of the results for the stirred melts is that reaction (i) is rate controlling.

In the case of the unstirred melt (experiment 1) k_2 is not negligibly small (with the results so far obtained) and the above hypothesis is untenable. A reason for this is that when the slag is quiescent, the FeS concentration on the slag side of the tenacious metal film (unfortunately not measurable) is no longer negligible and consequently, [S] in the bulk of the metal is no longer a measure of the concentration drop across the film. In other words, except at the very beginning of the melt,

4 Goodeve, C. F. Discussions of the Faraday Society, No. 4, 1948, "The Physical Chemistry of Process Metallurgy," p. 9.
5 Holbrook, W. F., Furnas, C. C. and Joseph, T. L. *Indust. Eng. Chem.*, Sept., 1932, p. 993.
6 Darken, L. S. "Basic Open Hearth Steelmaking." A.I.M.M.E. (1951).

slag sulphur diffusion (which was largely avoided by convective sulphur transfer in the stirred melts) is markedly affecting the overall rate of sulphur transfer. This is consistent with the work of Derge, Philbrook and Goldman[2] who found that the diffusivity of sulphur in CaO-SiO_2-Al_2O_3 slags is roughly ten times less than that in carbon saturated molten iron.

It is hoped to perform further work on this subject which will include a study of such variables as slag/metal weight ratio, concentration of sulphur, slag composition and temperature.

Acknowledgments

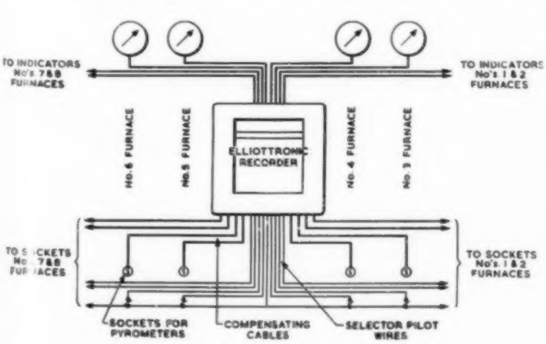
The author wishes to express his gratitude to Mr. F. J. Lund for carrying out the melting and the chemical analysis, and to Dr. A. H. Leckie, Head of the Steelmaking Division of B.I.S.R.A. for his helpful advice, and for permission to publish the paper.

Interesting Liquid-Steel Pyrometry Installation

ELSEWHERE in this issue will be found an article dealing, in general terms, with immersion pyrometry in the steel industry, in which is emphasised the importance of the accurate measurement of steel temperature in the open hearth furnace. The problem is one to which much ingenuity has been applied by instrument makers, for, at temperatures above 1,600° C. such as are encountered in the open hearth furnace, the total time for which a thermocouple will withstand immersion is limited to a few seconds, and the indicating or recording instruments employed must be responsive and dead-beat to enable the operator to determine the temperature of the steel accurately.

The conditions associated with an open hearth make it essential to use a large and robust indicating instrument with a long scale, so that the movement of the pointer can be followed accurately and easily in the time available. With rare-metal thermocouples the E.M.F. available is insufficient directly to operate a large indicating instrument or a graphic recorder of the deflection type, and the choice is between an indicator and amplifier, a self-balancing potentiometer indicator or a high-speed self-balancing recorder, all of which are heavy instruments needing mains supply and difficult to carry from furnace to furnace.

The problem has been solved in the new melting shop at the Abbey Works of the Steel Company of Wales in a novel and, it is believed, original manner. Here there are eight open hearth furnaces, each of 200 tons capacity, in use or under construction. A single recorder is used for steel temperature measurement and recording purposes and local indication at all the furnaces is provided by 12 in. long-scale indicators which repeat the recorder readings. The Elliottronic recorder, which has a compressed zero range, is mounted on one of the



Wiring arrangment for the installation

Elliottronic recorder installed below local indicator on No. 5 furnace.

furnace control panels centrally in the melting shop. Compensating cables and pilot wires are brought out to sockets provided near each of the furnace control panels, enabling the immersion pyrometer to be plugged in at any one of the eight furnaces.

When the steel temperature of any furnace is to be measured, the immersion pyrometer is plugged into the socket provided near that furnace instrument panel by which it is connected to the Elliottronic recorder. The insertion of the pyrometer plug in the socket also closes a pilot wire circuit and automatically starts the recorder chart drive and operates a selector switch which connects the appropriate local repeating indicator. The selector also makes a mark on a narrow strip on the left hand edge of the chart to identify the chart record with the furnace at which the reading is taken.

Immediately the pyrometer is immersed, a temperature record is obtained on the central recorder and the temperature indicated locally on a large instrument on the furnace instrument panel where it can easily be observed from the charging stage. When the pyrometer plug is removed the recorder chart drive stops automatically and so prevents undue wastage of chart paper.

Central Creep Test Research Station

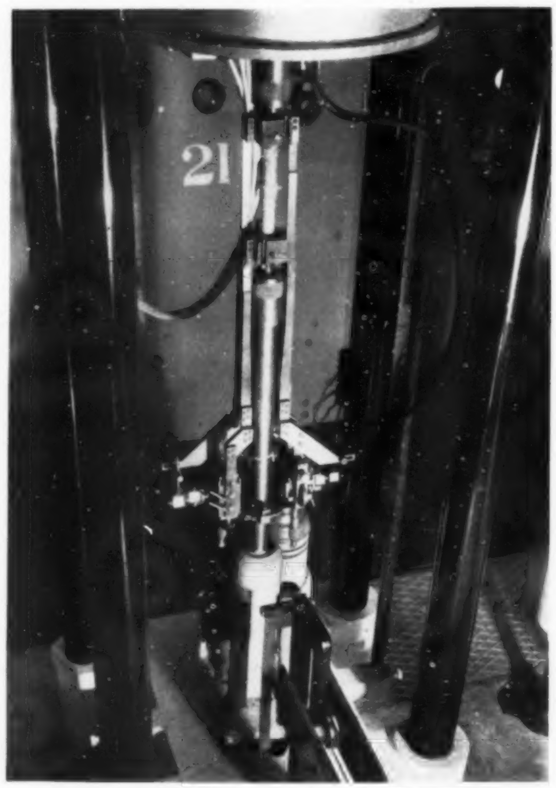
New I.C.I. Development at Witton

THE steady rise which has taken place in the last two or three decades, in the service temperatures at which metals are required to operate, has been accompanied by a correspondingly increased interest in the subject of metallic creep. Although exploratory work had been published previously, the serious study of creep phenomena could not be said to have started before the early 1920's, when it was established that, not only do metals stressed at elevated temperatures undergo progressive deformation with time, but that fracture can occur at stresses much lower than those required to cause failure in a short-term elevated temperature test.

In the main, the purposes for which metals are used at elevated temperature involve the sustenance of load for a long period, a notable exception to this being the aircraft gas turbine, whose life is relatively short when compared with the 100,000 hours or more expected of a first-line power station steam turbine. Data suitable for design work on long-life plant can only be obtained from long-term testing, which involves the use of a number of machines if several tests are to be conducted simultaneously. There have, accordingly, been many attempts to introduce more rapid testing procedures coupled with some form of extrapolation, but, to date, none of these have proved entirely satisfactory. This is not altogether surprising when it is appreciated that structural changes may take place in a material when held for long periods at elevated temperatures, and that such changes may significantly alter the material's resistance to creep. Nevertheless, much useful guidance in assessing the relative merits of different materials can be obtained by accelerated testing, thus preventing waste of time and machine capacity in testing the inferior materials.

While many industrial firms and technical organisations have equipped themselves with the necessary apparatus for obtaining creep data, the demand is greatly in excess of machine capacity. I.C.I. has developed, or is developing, many chemical processes which call for accurate knowledge of the strength of metals at elevated temperatures so that new plant shall be economically designed and safely operated. In addition, I.C.I., through its Metals Division, manufactures wrought non-ferrous metals and alloys and, as an essential service to its customers, must be in a position to provide full technical data on the properties of its products, including, of course, properties at elevated temperatures. In order to meet the needs of its own designers, and those of its customers, the Company has, therefore, built and equipped a Creep Test Research Station, located at Witton, Birmingham, and operated for the Company by the Metals Division.

As will be seen from the illustration, the building comprises a well-lighted two-storey block with a long, windowless, single-storey wing in which the testing units are installed. Space is available on the other side of the two-storey block for a second testing chamber in which additional apparatus could be housed. The first floor is occupied by offices and rooms for calibrating thermo-



Close-up of testing unit with furnace raised to show metal specimen installed.

couples and for servicing the many electronic devices employed. There is also a records room, where results of test observations are filed daily, and the development of creep curves is plotted. The view of the inside of the completed test room shows the two types of testing machines installed. The larger units are grouped into four batteries of nine, standing upon separate concrete rafts, well insulated from the main foundation of the building. Twenty-four small machines are mounted on concrete plinths at one end of the laboratory, whilst hollow concrete benches, disposed centrally along the room, support accurately-aligned metal rails which serve as runways for the telescopes employed to measure the extension of the specimens in the large machines.

General view of test room

Air-conditioning plant keeps the room temperature at 68° F. and controls humidity at a satisfactory working level, namely, 60% Relative Humidity. This, carefully conceived lighting and a pleasing colour scheme ensure congenial working conditions, essential in view of the rather tedious nature of some of the observational work.

The smaller machines, based on the design of Oliver and Harris, are employed solely for the derivation of data needed to prepare stress/rupture curves. These machines incorporate four vertical columns, screwed into a bedplate and supporting the top cross-head, over which is placed a 10 : 1 reduction lever. The top shackle is attached by universal joints to the short arm of the lever; a flat weight-holding pan, hanging from the knife-edge, is connected to the other arm. When a specimen has been screwed into the shackles, the bottom one of which is attached to a straining device, the appropriate load is placed on the weight pan, supported as yet on a wooden stand. By adjustment of the straining handles, load is gradually transferred to the specimen.

An essential feature of each testing unit is a suitable furnace. The type provided for these small machines incorporates three separately wired zones, with control of input effected by a stainless-steel/Invar bar thermostat system. Separate platinum/platinum-rhodium couples are attached to the top and bottom of the 1-in. gauge length of the specimen and the leads carried to potentiometers and to thermostatically controlled cold junctions. Two twenty-four point selector switches are incorporated in the temperature-measuring circuit, these being connected to each of the forty-eight couples distributed among the twenty-four machines. In each furnace an additional couple is strapped to the centre of the specimen length and is led to a six-channel autographic temperature recorder, of which ten are installed in the records room.

Design of the larger machine is based on that developed by the National Physical Laboratory. This type of unit is used to provide data necessary for the establishment of families of creep curves. Ancillary equipment for each machine includes highly sensitive extensometers of the Martens type, disposed on either side of the specially shaped test specimen, ensuring the ready detection of deviation from axial loading. Crossed knife-edges, situated as far away from the specimen as possible are fitted to the top and bottom shackles of the machines. A maximum load of 5 tons can be applied to the specimen.

When a test is in progress, the inner pair of mirrors associated with the extensometer arrangement is connected through rhomb-shaped spindles to the moving and fixed limits of the instrument, and as the specimen extends there is angular displacement of these mirrors relative to the outer pair. The light source and optical system used are such that the extension is magnified two thousand times and an extension of the specimen of $19 \cdot 7 \times 10^{-6}$ in. ($0 \cdot 5\mu$) can be readily detected.

To avoid interference with the beam of light, whose source is adjacent to the telescope, the hand-operated straining gear of the machine is placed above the top cross-head, while a graduated steelyard, carrying the moving poise weight, is placed just above the bedplate.

The furnace unit employed is housed between the four vertical columns of the machines; balance weights aid raising and lowering. Details of design were arrived at after a certain amount of development work, during which it was established that to maintain the temperature gradient at as low a value as possible, the ratio of the length of the furnace to the length of the specimen should not be less than 4 : 1. This preliminary work also clearly established the need to incorporate at least three separately controlled heating zones, and to employ differential winding for the top and bottom pair. A platinum resistance thermometer, permanently installed in the furnace tube, monitors an electronic unit, so automatically controlling current input to the furnace.

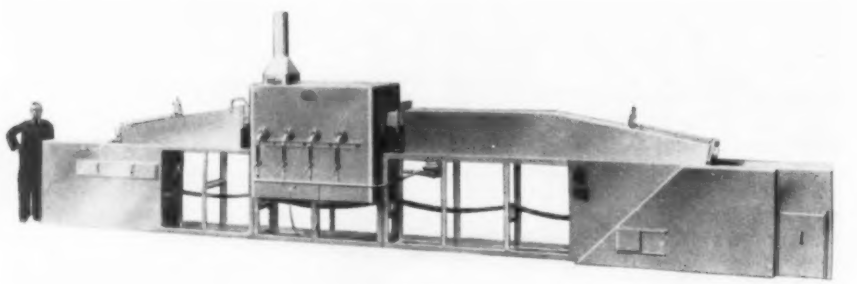
Four platinum/platinum-rhodium thermocouples are used to measure the temperature of the test specimen mounted in the machine. One of these is strapped at the top of the gauge portion of the specimen, two in the middle, and one at the bottom.

Leads from three of the couples are taken to a phenolic resin connection box screwed to one of the rear vertical columns of the machine and then carried to a vernier potentiometer reading to 1/12° C. This instrument serves eighteen of the larger machines, three eighteen-point selector switches being mounted on the panel. Two potentiometers make it possible to check temperature rapidly at the top, middle or bottom of any of the thirty-six specimens. Leads from the duplicate middle couples of all specimens are carried to one of the ten six-channel autographic temperature recorders already mentioned, so that any untoward variation in temperature can be detected at a glance.

When the extension of the specimen over long periods is being studied, the importance of maintaining uniforn temperature is obvious. Experience has indicated tha the monitoring of an electronic controller by a platinun resistance thermometer, in association with the desig of furnace employed, ensures that the terms laid down i British Standards 1686 and 1687 (1950) for high an medium sensitivity tensile creep testing respectively, ar readily met. By contrast, a mechanical temperatur controller is used on the smaller machines ; even so, th conditions laid down in British Standard 1688, which refer to stress-to-rupture testing, are adequately covered.

Although the main function of the Statior is to establish design data, some equipment will be devoted to fundamental research on creep behaviour.

Gas Fired Continuous Bright Annealing Furnace



BRIGHT annealing is now a well-established process which finds particular application in the light engineering industry where large numbers of small parts such as pressings, stampings, etc., are produced.

Our illustration shows a modern example of a belt conveyor furnace, heated by town's gas, in which hydrogen is used as the medium for bright annealing the small parts commonly used in the radio and telephone industries. It is of the natural-draught muffle type with an inlet zone 6 ft. 3 in. long, a heated section of 5 ft., and a cooling zone of 11 ft. 3 in. The overall length of 29 ft. includes the charge and discharge structures with their conveyor belt pulleys. The furnace is suitable for operating at a maximum temperature of 1,050° C.

A 7 in. wide heat-resisting steel mesh conveyor belt passes through the furnace and over pulleys whose faces are specially treated to give a good grip. At the discharge end, the belt passing round the pulley is also pressure loaded to improve still further its smooth transmission, and as a consequence no tensioning need be applied to the return strand. The life of the conveyor will be greatly prolonged compared with that used in older type furnaces.

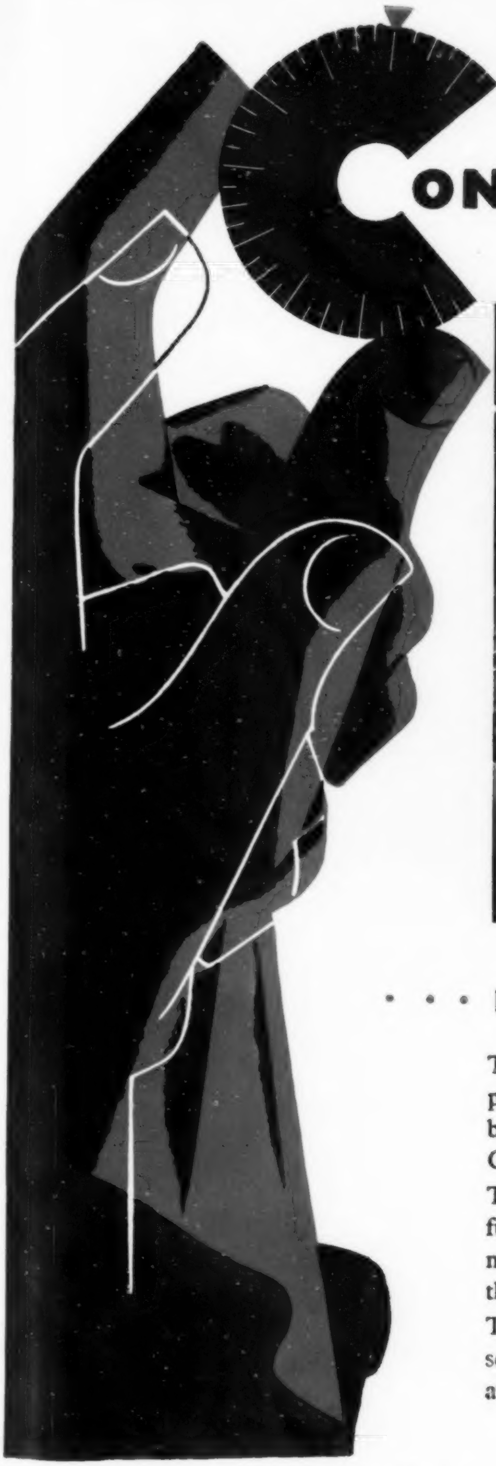
The driving unit is totally enclosed in an attractive sheet steel guard and consists of a ½-h.p. electric motor connected through a 4 to 1 variable-speed gear unit to worm reduction gears and finally through a roller chain drive to the discharge-end driving pulley, giving a speed variation of throughput between 15 and 60 minutes. Adjustment is easily effected by a sliding steel door in the guard case giving access to the speed regulating knob.

The furnace section is built of light-weight insulating refractory, backed with diatomaceous insulation enclosed in a steel casing having rounded corners. Heating is by eight venturi-type atmospheric burners firing under the muffle alternately from side to side. The maximum gas capacity is 600 cu.ft./hour at 3 in. w.g. pressure, which enables the furnace to be heated from cold to a temperature of 800° C. in 1¼ hours. The furnace is capable of an output of 80 lb./hour of non-ferrous pressings, and at a temperature of 800° C. has a consumption of approximately 300 cu. ft. of town's gas/hour.

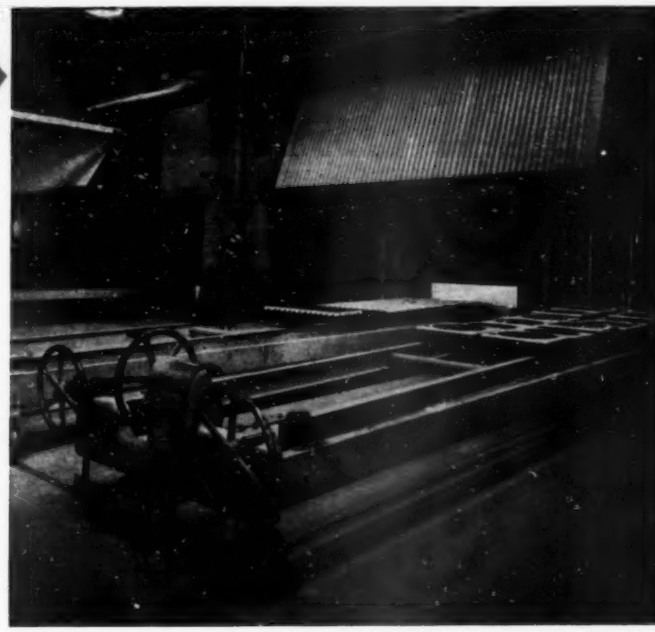
As a result of the furnace having a " hump back," and the use of adjustable mouth pieces at the inlet and outlet, the consumption of atmosphere gas used during production is very low. The variable belt speeds, together with flexibility of heat input and automatic temperature control, make this Dowson and Mason designed furnace of interest to many manufacturers engaged in bright annealing or similar processes.

Fine Wire Supplies

BRITISH DRIVER-HARRIS CO., LTD., of Manchester, announce that their Fine Wire Section has been considerably extended and re-equipped for the production of standard nickel-chrome, copper-nickel and pure nickel wire, in sizes down to 50's S.W.G. New machines of the most modern pattern have been installed, and we understand that the present delivery is good.



CONTROLLED HEAT...



Photograph by permission of Parnall (Yate) Ltd.

. . . FOR VITREOUS ENAMELLING

This muffle furnace is used for the vitreous enamelling of pressings for washing-machine bodies. It was built and designed by Th. Teisen C.E. of Birmingham for Parnall (Yate) Ltd., Gloucestershire.

To ensure economy in the use of oil fuel, waste heat from the furnace gases is used to preheat the combustion air to approximately 200° F by means of a U-tube recuperator and to pre-dry the ware.

The working temperature is 850°C and the furnace load 400 square feet of 18 gauge plate per hour, the oil consumption averaging 10 gallons per hour.

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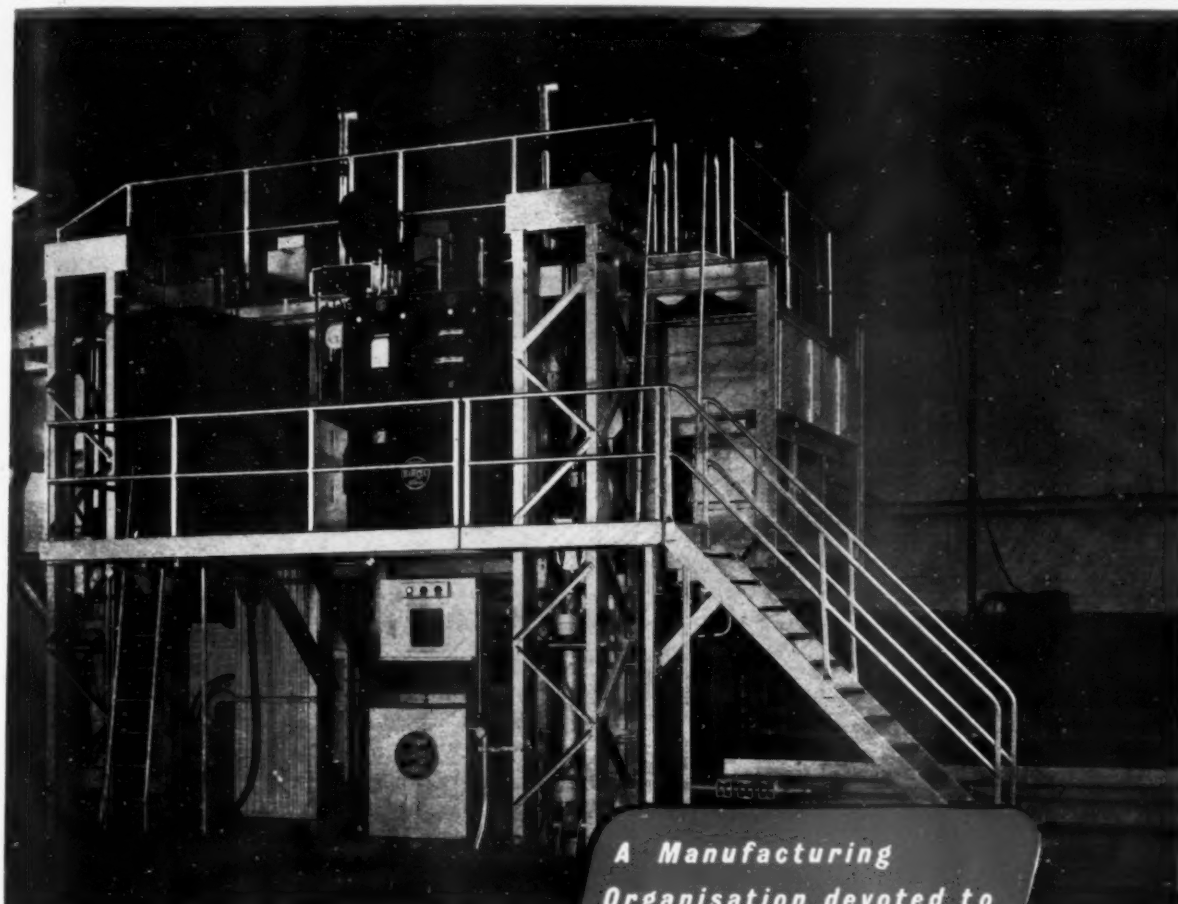

Automatic Control and Recording Pyrometers on electrically heated annealing furnace for malleable iron castings. Illustration by courtesy of Messrs. Birlec Limited.

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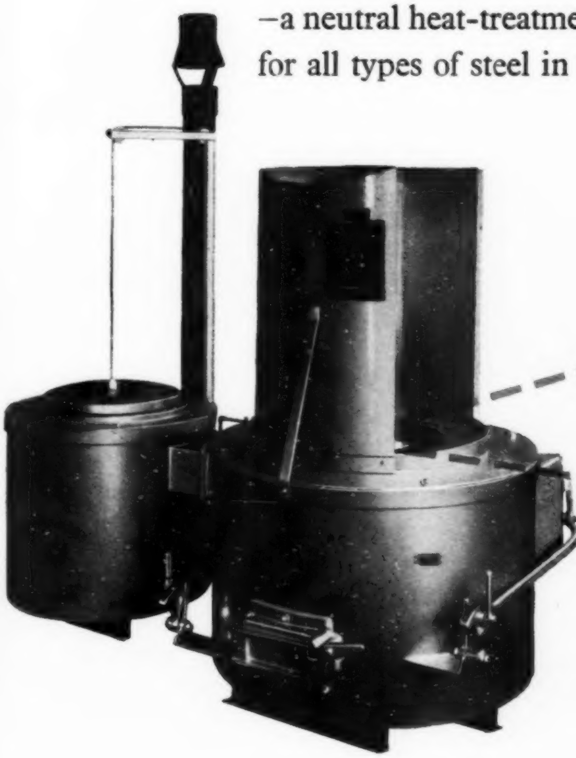

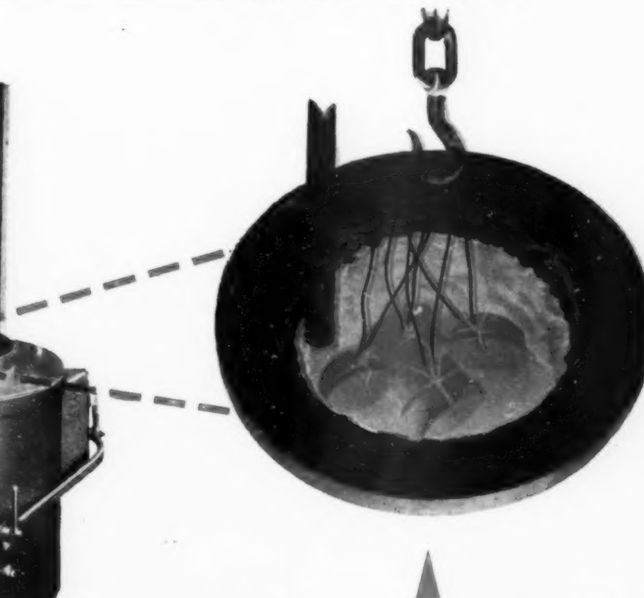

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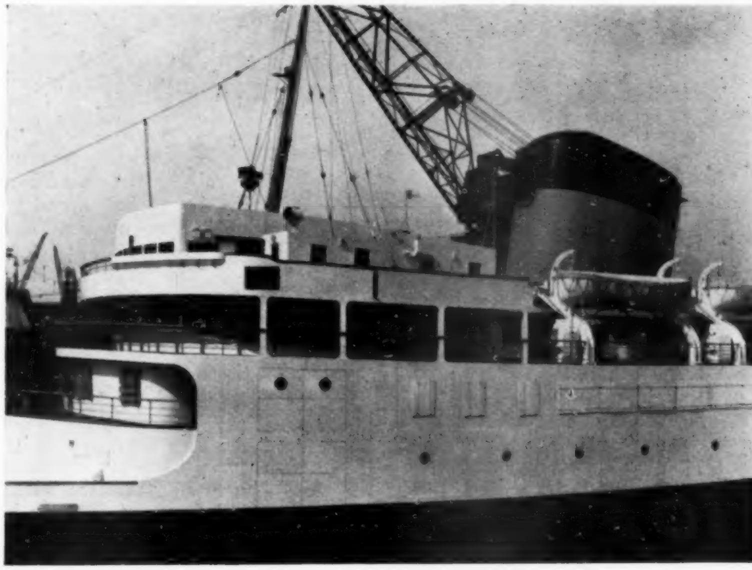
Progress in Aluminium and its Alloys

Current Applications and Future Prospects

By P. L. Martyn
The British Aluminium Co., Ltd.

Since 1945, aluminium has entered a new phase of development, and its increasing use as an engineering material has led to the adoption of new techniques appropriate to the properties of light alloys. Attention is drawn to a number of interesting applications and future prospects are discussed in the light of the rearmament programme and growing production capacity.



Courtesy of The British Aluminium Co., Ltd.

The boat-deck superstructure and after-deckhouse of the 'Princess of Nanaimo,' built by the Fairfield Shipbuilding and Engineering Co., Ltd., were fabricated in aluminium to reduce top weight.

IN 1952, the rearmament programme once more poses to the Aluminium Industry some of the problems it has already encountered in the two World Wars which have occurred during its sixty years of commercial development. It is, accordingly, opportune to appraise some of the existing applications of aluminium and to consider future development prospects. Much attention has been paid recently to the lack of balance, throughout the world, between the output of manufactured goods and the supply of raw materials. If present trends in the metal industry continue, the increased production of aluminium, magnesium and, possibly at a later stage, titanium seems most likely to provide a long term solution to the present difficult raw material supply position.

The potential abundance of aluminium, and the ambitious plans under way throughout the world to expand production far above the peak achieved towards the end of the 1939/45 War, raises the question of possible excess production, particularly after the main rearmament effort has been made. A similar prospect faced the Industry in 1945, but the civilian market rapidly absorbed the fabricating capacity of semi-manufactured aluminium which had been expanded five-fold between 1939 and 1945. There is, accordingly, historical evidence to suggest that future increases in capacity rising from the world-wide rearmament programme will be maintained in operation on a return to more peaceful conditions. In an industrial society, the raw material demands of war or extensive re-armament and of a civilian industry catering for a world population with a rising standard of living are essentially the same.

Prior to the 1939/45 War, aluminium was considered, along with the other non-ferrous metals, as ancillary to wood, stone and steel. During the past six years, aluminium has progressed from its former position as a subordinate material to that of a complementary metal to steel. There is still much ground to be covered before aluminium can be considered a serious competitor of steel. Even when the new smelters in the U.S.A. and Canada come into operation, world aluminium production will not exceed three million tons per annum, and will form about $1\frac{1}{2}\%$ by weight of the total steel production.

The higher cost of aluminium also prevents its economic use as a direct substitute for steel. Technical development work since 1945 has shown, however, that there are many applications where aluminium can be used to commercial advantage because it is functionally more efficient than steel. Alone among the non-ferrous metals, to keep pace with the general level of rising productivity, aluminium is likely to replace copper, zinc and lead in many applications.

The future, accordingly, portends increased attention being paid to the technique of applying aluminium to an existing use or to an entirely new application. Mere substitution of another material is rarely efficient technically, nor is it economical in the long run. Both alternative uses and new applications demand careful analysis of the relevant facts, and in many cases a return to first principles is desirable. The manner in which the leading industries are tackling the present situation is

worthy of careful examination. Conditions naturally vary from industry to industry, but a comparative study of manufacturing techniques can be most rewarding, for the solution of a particular problem in one industry very often points the way to the solution of a related problem in a quite different industry. Such comparative studies, so valuable in other subjects, may make a fruitful contribution towards increased productive efficiency.

Road Transport

Road transport is one of the largest consumers of aluminium. In goods vehicles, the aluminium alloy body on a steel chassis is well established, especially for 30 m.p.h. vehicles which must come within an unladen weight limit of 3 tons. In larger vehicles, more aluminium bodies are being used to increase payloads and cut maintenance costs. Operators know running costs accurately and adopt all means of reducing them, even at the expense of slightly higher initial capital expenditure.

It was thought that in passenger vehicles the next step forward would be from the aluminium body on a steel chassis to all-aluminium chassisless construction. This has not happened, probably because it would have brought about the fusion of two distinct sides of the Motor Industry which are quite different in character. The chassis builders, in general, are small in number but large in size, whereas the bodybuilders are large in number and small in size. This combined technical and industrial problem has been solved by the under-floor engine chassis which allows increased passenger accommodation and a low centre of gravity, and is so designed that the body plays a full part in the stress carrying capacity of the vehicle. To take full advantage of the weight saving obtained by using aluminium in road vehicle design, it is desirable that the chassis makers should make available special axle ratios for incorporation in light-weight vehicles.

In the use of aluminium, Britain is ahead of most other countries, although on the Continent, notably in France, more aluminium is being applied to private cars than in this country. The extensive use of aluminium in the higher priced coach-built cars over the last forty years is, however, being gradually followed in the mass-produced medium-price car range. The marketing of a small mass-produced light-weight aluminium private car has yet to come in this country.

Aluminium alloys of the heat-treatable Mg_2Si type (H10) are generally used for structural members, with the addition of the non-heat-treatable aluminium-magnesium alloys for stressed sheet, the $1\frac{1}{4}\%$ aluminium-manganese alloy (N3) being used for unstressed sheet. In structures liable to severe plastic deformation, some manufacturers still prefer the heat-treatable copper-containing alloys.

When improved welding processes become commercially available, welded construction will be attractive, especially for tipping-vehicles and bulk transporters. The development of a satisfactory and competitively priced aluminium alloy wheel to reduce unsprung weight is an urgent requirement.

Shipbuilding

Aluminium has been used over a long period for non-structural applications in ships, but more recently it has been recognised as a structural material having outstanding properties. Of the aluminium alloys approved by Lloyd's, the medium strength weldable aluminium alloy of the $3/5\frac{1}{2}\%$ magnesium type (NP5/6) is being extensively used for plate. At present, in riveted construction, such plate, in combination with heat-treatable Mg_2Si alloy in the form of section (HE10) and 5% magnesium alloy in the form of rivets (N6), is generally employed for heavy scantlings. As welding can offer further weight saving, the evolution of an efficient welding technique for shipyard service is urgently needed. The 'Aircomatic' process, with its continuously-fed consumable argon-shielded aluminium alloy electrode and automatically controlled arc, gives a welding speed some three times as fast as mechanised argon arc welding. This process is likely to revolutionise aluminium alloy shipyard operations, and it is to be regretted that it should have been put into large scale use in the United States before it has even been tried in this country. It is significant that the British welding team which visited America in 1950, under the auspices of the Anglo-American Council on Productivity, singled out this process as being worthy of special mention in their findings, and stated that this was the only technical field in which American welding techniques were appreciably ahead of British practice.

Available aluminium alloys permit a weight saving of about 60% to be achieved compared with steel. The weight saved can be used in a number of ways, notably to increase stability, decrease displacement and draught, or increase deadweight. Better durability reduces maintenance costs and the lower Young's modulus of elasticity can be used to overcome the difficulties encountered in the stress distribution in the long deck-house of a large ship. These factors make it certain that the Shipbuilding Industry will ultimately become one of the largest consumers of aluminium alloy. Extensive tests have shown that the standard fire protection methods are quite satisfactory for aluminium superstructures.

As an indication of the current trend, the new transatlantic liner *United States* employs some 2,000 tons of structural aluminium alloy in her superstructure. Aluminium was specified because, for a given passenger accommodation, the desired stability could be obtained with a marked reduction in beam as compared with all-steel construction. This allows estimated fuel costs to be cut by about £100,000 per annum and, furthermore, the first cost of the ship was reduced.

The Railways

With the exception of The London Transport Executive, British Railways have lagged behind in the development of aluminium rolling stock compared with other countries, notably France, U.S.A. and Switzerland. It is significant that the use of aluminium is often related to the accuracy with which running costs can be ascertained. In suburban electric rolling stock, operating costs are readily available and the saving due to weight reduction can be calculated. The fact that operating costs do not seem to be so readily available for steam traction has undoubtedly held up aluminium developments on the other railway systems. The aluminium rolling-stock shortly to come into service on the Metropolitan Line (L.T.E.) points to future possibilities.

Aviation

The rearmament programme has naturally caused an increased proportion of the Aluminium Industry's output

to be temporarily employed in the production of aircraft material, for which aluminium has long been the pre-eminent metal for structural members. In the 1939/45 War, the heat-treatable 4% copper alloys continued to form the bulk of aircraft material production. Research and development work on the newer heat-treatable 6% zinc, $2\frac{1}{2}\%$ magnesium alloys, having improved mechanical properties compared with copper-containing alloys, have made possible further weight saving. Undoubtedly, in the future, a growing proportion of aircraft material production will be in these alloys.

Courtesy of Almin, Ltd.

Aluminium aircraft hangars at London Airport with the first bay complete and the second and third bays under erection. Design and construction by S.M.D. Engineers, Slough.

In the Aircraft Industry, advances in design provide a continuous stimulant to the further developments of both methods of manufacture and fabrication. High-speed aircraft must have wings that are thin and strong, and at the same time stiff and smooth. This difficult and challenging design problem has been tackled in a number of ways, notably in America by the extrusion, using a high-capacity press, of large diameter tube with stiffeners attached, which is subsequently split and flattened to provide an integrally stiffened panel. In this country, special machining methods are being investigated to produce integrally stiffened panels from thick plate. Another approach to the same problem is to attach stiffeners by means of suitable synthetic adhesives.

The supply of very large extrusions and large thick plates in these new alloys has presented fresh problems to the metallurgists in the Aluminium Industry. Good progress is being made towards the solution of the major problems such as the minimising of the distortion after machining, and the elimination of variation in strength and ductility across very thick plate and section.

Building

The Building Industry is now a large consumer of aluminium, and typical applications include roofing sheet, glazing bars, rainwater goods, shop fittings and decorative work of all kinds. Scaffold tube in aluminium alloy of the Mg_2Si type (H10), first used as a direct substitute for steel during the acute steel shortage in 1946, has come to stay, due to its inherent advantages of light weight and durability, and rainwater goods, in both cast and wrought form, have been much appreciated, due to the elimination of the higher breakage rate as compared with cast iron.

In the U.S.A., window manufacture provides a large market for aluminium, and when supplies of metal become freely available, the wider use of aluminium windows can be expected in this country. Encouraging progress is also being made in the application of Super Purity aluminium (99·99% purity) for flashings and weatherings. This material has exceptionally good corrosion resistance and high ductility, and in ease of forming is second only to lead. Jointing techniques have been evolved by craftsmen plumbers, based on their experience with copper and lead, and are proving most satisfactory.

The unceasing quest for a satisfactory method of producing a sandwich from two skins of aluminium (in order to take bending stress) and a filler (to take shear stress) has continued in the building, aircraft, and structural fields. An interesting solution to this problem was employed in a roof on the 1951 Exhibition site. A cork slab was used as the filler on to which were glued, using a synthetic adhesive, two $1\frac{1}{4}\%$ aluminium-manganese alloy (N3) skins. This sandwich, as well as being light and strong, also provided a high degree of heat insulation. A filler material having a durability comparable under all conditions to that of the aluminium skins has so far eluded discovery.

A new market for aluminium strip lies in the manufacture of venetian blinds, the thin metal slats giving a compact, durable and clean blind. Aluminium is unaffected by termites and has better corrosion resistance than steel. Corrugated aluminium sheet is being employed for roofing purposes at home, generally for industrial buildings, and abroad in tropical areas for housing. An amusing advantage of aluminium has been reported from Africa. In a certain area it is the custom to assess a man's social status by the roofed area of his house. After the annual visit to the town, the purchases are carried home on the heads of his wives. That wives are able to carry three times as much corrugated aluminium sheet as compared with galvanised iron has been much appreciated—by husbands anxious to rise in the social scale.

Structural Engineering

The publication of the "Report on the Structural Use of Aluminium Alloys in Buildings" by The Institution of Structural Engineers at the end of 1950 has provided a sound basis for design-work and includes the data needed to draft a contract specification. As further

Courtesy of " The Aeroplane".

The de Havilland ' Comet ' jet airliner is an outstanding example of the application in aircraft of aluminium construction.

experience is gained, it can be expected that the requirements of the Report will be amended and, in particular, in certain cases the permissible working stresses increased.

Research has been carried out on the driving of large diameter aluminium rivets in the range ½ in. to 1 in.; recommended heading procedures are available and a British Standard is in preparation. An instructive feature of this work was that after unsuccessful attempts at direct substitution of appropriate aluminium alloys to the dimensions of steel rivets, a rational approach to head shapes was made. It was then found possible to reduce the diameter and height of a pan rivet head by 12% and 25% respectively, but still provide a rivet head as strong as the shank in tension. In many structural applications, smaller heads are permissible, as a rivet is essentially a shear connection, and engineers have already predicted the use of headless rivets.

The response of the universities to the advent of aluminium as a structural material has been most encouraging. A considerable proportion of the facilities available for research on structures is being devoted to investigations into the behaviour of the aluminium alloys. Fundamental research promises to lead to the design of an improved range of compression-member sections, which will incorporate generous corner radii and bulbed outstanding legs. Such sections can be produced with ease by the extrusion process which is the normal production method in the Aluminium Industry, in contradistinction to the hot rolling method used for steel. At a later stage, it is hoped that BS.1161 : 1951 "Aluminium and Aluminium Alloy Sections" will be extended to cover both improved sections of the existing shapes and, possibly, entirely new forms.

Design practice has been conditioned by two factors, the first due to aluminium's low Young's modulus of elasticity, and the second due to its relatively high price. Both factors prevent efficient or economic direct substitution of structural aluminium for steel. Designers have, accordingly, used as little metal as possible by employing special thin walled extruded sections and built up latticed work construction, rather than plated sections.

Since 1945, aluminium has been used for all the classic cases, with the exception of the long-span bridge, where its properties offer outstanding advantages. Such cases are long-span overhead cranes and jib cranes, bascule bridges, long-span roof structures, and the maintenance of performance from existing structures. At the present time, a possible development of special interest is the proposal to convert the Forth Bridge into a combined road and rail bridge without modification to the primary structure. This could be done by replacing the single steel deck by a double deck fabricated in aluminium alloy.

Now that case histories are available to show the suitability of aluminium for large structures, the future holds promise that aluminium will be used in the bridge-building schemes which may be put into effect on a return to more normal conditions. In the immediate future, structural aluminium can be expected to be used in an increasing number of structures where inertia of moving parts, stress due to self-weight, or maintenance, are basic factors in design.

Mining

Aluminium has been used for the construction of skips and cages for many years, especially in the African gold mines, and more recent applications in Britain have proved most successful. Light-weight equipment is of inestimable help to the miner, working as he so often does in confined and difficult places. Continental experience with extruded and forged aluminium alloy supports and roof bars is now being tested in this country. A new type of aluminium alloy yielding prop weighing 50 lb. and capable of carrying a load of 40 tons is much more efficient than the equivalent steel props in use. Measures being taken to improve the efficiency of underground haulage systems include large scale experiments with aluminium tubs and cars.

Electrical Engineering

The principal application in the Electrical Industry, both at home and abroad, has been the use of steel-cored aluminium overhead cable. As industrial production increases, so the necessity for more electric power stations and for the provision of overhead lines arises. Not only will aluminium be used for the high-voltage lines, where its technical advantages are paramount, but also in place of the copper used in distribution transformers and, eventually, in power transformers, because of the long-term shortage of the latter material. Busbars, although only used so far to a limited extent, will, for similar

reasons, become specified more frequently in the future. Suitable techniques for using aluminium in this application are well developed, and long service experience provides abundant evidence of suitability. For electrical purposes, it has been the usual practice to use special purity aluminium of 99·5% or higher, in order to obtain the necessary electrical conductivity. It is likely that, in the future, jointing techniques will be evolved to enable aluminium to be used for the conductors of insulated cable. Encouraging progress in this field has already been made in the U.S.A. and France.

Shortages in other non-ferrous metals have brought into increased prominence the use of aluminium for cable sheathing, and many leading cable makers are carrying out researches into, and in some cases marketing, aluminium sheathed cable. For certain methods of production, Super-Purity aluminium is ideally suitable owing to its high ductility and consequent ease of extrusion, while, in other cases, lower purities and alloys of the $1\frac{1}{4}$% manganese type (N3) are being used or investigated, either as swaged seamless or welded tubing.

Chemical and Food Industries

A substantial market has existed for many years in chemical plant, where the special properties of aluminium often make it suitable. Classical examples of such use are in conjunction with acetic and nitric acids and, more recently, with the synthetic detergents, while food processing plant continues to be an important application. In the production of gas, aluminium is being employed because of its better resistance to sulphur compounds than steel, and sewage equipment is another expanding application. In the future, aluminium may be used instead of copper for condenser tubes and heat exchangers, encouraging progress in these fields having been made in the U.S.A. The increased production of synthetic chemicals complementary to the home petroleum refining industry, is another future outlet for aluminium, both for processing and distribution.

Packaging

Industry as a whole has recognised the public demand that more products should be efficiently packed, and only the ingot shortage has prevented greater quantities of aluminium sheet and strip being produced to meet the expanding requirements of packaging. The Fish and Meat Industries are likely to become large consumers of aluminium in the future. Aluminium will be used for many applications where tinplate has been used, and this is particularly the case for dry-pack products, and for capping purposes, whilst intensive research into the commercial development of aluminium wet-pack cans continues. Impact-extruded rigid and collapsible-sided aluminium containers are receiving much attention, particularly the latter, due to the high price of tin. In the same way, foil production will continue to increase, because it has the lowest water vapour permeability of any of the common film materials. A newer use is as a barrier in composite materials made from paper, fibre and synthetic films, such as cellulose acetate. For the larger types of container, aluminium of 99·5% purity or higher is being used for the transport of hydrogen peroxide. Aluminium milk churns in the heat-treatable Mg.Si type alloys (H10) are used on a large scale on the Continent, whereas trial batches only have been put into service in Britain.

Conclusion

Since 1945, certain trends have become more apparent in the Aluminium Industry. Technologically aluminium has entered a new phase of development : at first, in the heavier industries, the higher strength alloys were necessarily used in ways analogous to those well established for steel, but as experience has been gained, there has been a marked tendency to break away from steel design practice and adopt new techniques appropriate to the properties of aluminium. New welding processes are likely to revolutionise aluminium construction by making further weight reductions possible, which will greatly extend the range of worthwhile structural applications. To meet these new demands, the Aluminium Industry has installed heavier plant for the manufacture of the medium and high-strength alloys used in general engineering, and so is equipped to supply the largest finished plates and sections likely to be needed in the foreseeable future.

There has also been increased emphasis throughout industry on more efficient methods of packaging, to which aluminium can make a special contribution, either as thin sheet or strip, or as foil to be used alone or in combination with other materials. High-speed rolling mills have been installed for the large scale production of thin sheet or strip and foil, but must await freer metal supplies before showing their full potentialities. While the long term outlook for the Aluminium Industry is most encouraging, on a short-term basis supplies may be even more severely affected by the rising tempo of re-armament and, at the request of the Government, the Aluminium Industry has evolved a system of voluntary rationing of supplies according to end uses. This measure has been found necessary because supplies have had to be increased for defence work and yet maintained to industries with high export achievement. Although more aluminium has been made available overall during 1951 and 1952, as compared with 1950, it has been found necessary to reduce metal allocations to industries catering for consumer goods for the home market, in order to meet priority demands. In spite of all difficulties the problem is, however, relatively much smaller than in 1939/45.

Semi-fabrication capacity is more than sufficient to deal with the present ingot allocations and when, in two or three years' time, the new smelters come into large scale operation, the overall supply position will be much relieved. There are good reasons for optimism and there are many indications that, at the end of this turbulent period in world history, a great resurgence of aluminium developments will occur.

Instrument Association Luncheon

THE 8th Annual Luncheon of the British Industrial Measuring and Control Apparatus Manufacturers' Association was held in London last month. The Association represents more than 90% of the productive capacity for industrial instruments in Great Britain. There has been a phenomenal increase in demand for industrial instruments and controllers since the war, and to-day the automatic controller has taken charge of massive processes in every branch of industry, not replacing the operative, but enabling him to increase output and improve the quality of the product.

The Coating of Steel with Aluminium*

By D. P. Moses, B.Sc., A.I.M.† and G. G. Popham, B.Sc.(Eng.)‡

Aluminium coatings have made significant advances in recent years and future developments are expected to be even greater. In this article the present position is broadly reviewed and reference is made to the various methods for coating steel.

DURING the last six years, research and application have advanced so rapidly, that hot-dipped aluminium coatings on steel are now a commercial proposition. Improvements have also taken place in the other methods of applying aluminium, and this paper is an attempt to review broadly the present position.

The principal methods for the application of aluminium coatings to steel are given below in order of decreasing industrial importance. They are :—

1. Spraying Processes.
2. Calorising and Heat Treatment of Sprayed Coatings.
3. Hot Dipping Processes.
4. Cladding.
5. Casting.
6. Electroplating.
7. Vapour Reaction Process.

One of the chief characteristics of aluminium and its alloys is the persistent occurrence of a highly refractory and impervious film, which under normal conditions is usually thin. This alumina film rapidly reforms itself when ruptured, and advantage is made of this in utilising an aluminium coating on steel to promote resistance to corrosion and, in particular applications, to scaling at high temperatures.

Spraying Processes

The initial possibilities of spraying molten metal in a high-pressure gas stream were advanced by Dr. M. U. Schoop, of Zurich, and the direct outcome of this work is the Mellozing gun. This process is confined to the spraying of the comparatively low-melting point metals and suffers somewhat in that the pistol and auxiliary equipment are cumbersome to handle and may only be manipulated in a horizontal plane.

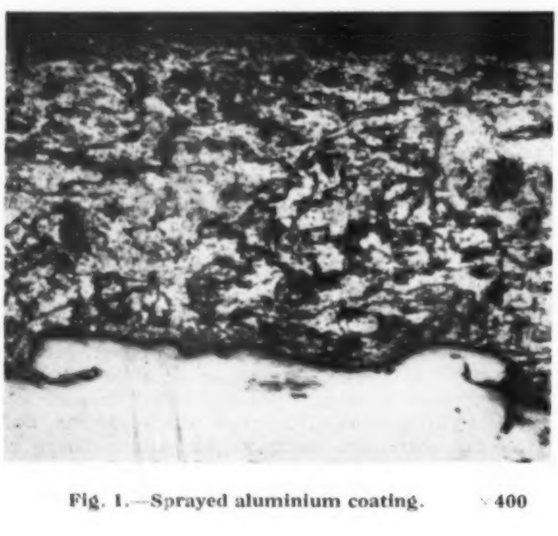


Fig. 1.—Sprayed aluminium coating. × 400

The Schori Metallising Process represents the latest technique in metal powder spraying, and consists essentially of the transportation of fine metal powders in a gas stream through a melting zone, with final subsequent acceleration of the molten particles by compressed air to impart the necessary speed for spraying to take place. This pistol is very easy to use, and a change-over from one material to another is quickly carried out. Important features of the process are that the pistol may be used in any position, and that it is easy to transport.

A variant of this process is the wire pistol method, in which the metal to be sprayed is fed into the pistol in the form of wire by means of a small air-turbine suitably housed within it. The turbine rotates at very high speeds, but is geared down to drive a pair of small rollers which feed the wire into the nozzle portion of the pistol, consisting of a flame surrounded by compressed gas, which atomises the molten metal.

The spraying of mixtures of metals and other materials is to-day carried out commercially.

A typical sprayed coating of aluminium is shown in Fig. 1, where it is seen that the coating structure consists of flattened metal particles enveloped with films of oxide. Adhesion is purely mechanical, and efficient keying of the sprayed coating to the basis steel is dependent upon the surface roughness of the latter. Sprayed coatings have certain limitations ; for example, they can withstand only slight deformation, and this restricts the process to finished products. In addition, the degree of uniformity attained is largely dependent upon the skill and care of the operator. Coatings of this nature also tend to be porous, but owing to its relatively high position in the electro-chemical series, this is not a serious drawback in the case of aluminium.

Calorising and Heat-Treatment of Sprayed Coatings

A feature of iron/aluminium alloys is their heat-resistance, and calorising is a process whereby sprayed aluminium coatings are suitably heat-treated to produce on the steel surface aluminium-rich layers ; appreciable resistance to scale-formation up to temperatures of about 900° C. is thereby conferred. This cementation process is also carried out by packing the cleaned articles in a drum containing aluminium powder and various additives—generally aluminium oxide to prevent

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fritting of the metal particles—and heating to a fairly high temperature in a non-oxidising atmosphere. Fig. 2.

The success of the process depends on the prevention of oxidation of the sprayed aluminium during the cementing period, and in order to obviate the use of reducing atmospheres, the following methods can be employed :—

(*a*) The application of a dilute solution of water-glass to the sprayed coating effectively seals off the latter to the air, and if the temperature of the article is rapidly brought up to 800° C., a successfully calorised product may be produced. Unfortunately, a glassy-brown slag is formed which tends partially to fuse and to detract from the appearance of the heated coating.

(*b*) Metallisation Limited have evolved a method in which a bitumastic paint replaces the water-glass seal. Rapid heating of the painted articles results in successful alloy formation and subsequent removal of the protective paint.

(*c*) It is claimed that small additions of deoxidising metals to the sprayed coating provide adequate protection from oxidation. 0·75% of cadmium in aluminium produces satisfactory calorised coatings when heated in a slightly oxidising atmosphere.

Hot-Dipping Processes

The difficulties associated with the problem of coating steel with aluminium by a hot-dipping process have long been known. The normal bath temperature (710–740° C.) induces rapid oxidation of the ingoing steel base, and as aluminium cannot reduce the iron oxide formed in the time available for dripping, alloying will not take place. It is essential that alloying should start as soon as the sheet is immersed in the molten bath, and this necessitates adequate precautions in the pre-treatment of the steel base to ensure absolutely virgin surfaces.

These difficulties were mentioned by E. J. Groom in his review of 1937.[1] In this he quotes the attempts of several investigators who employed such means as immersing the mechanically cleaned sheet and brushing it whilst in the bath,[2] or alternatively, pre-fluxing the sheet with a molten halide salt,[3] prior to dipping. Although alloying did take place with these processes, the coatings produced were most irregular.

Hot-dipping processes have now reached the stage of commercial application, and the methods adopted are:—

(*a*) The application of an intermediate protective coating to ensure adequate protection of the ingoing sheet or strip.

(*b*) Pre-fluxing methods.

(*c*) Pre-treatment of the strip with a protective and/or reducing atmosphere.

(*a*) *The Application of Intermediate Protective Coatings.* One of the earliest references to the use of intermediate coatings is obtained in Uyeno's Process,[4] in which the steel base is protected from oxidation by pre-coating with tin or zinc. The process is significant in that a serious attempt is made to coat steel continuously. The sheet passes through a series of aluminium baths, and simultaneous scratch brushing produces coatings which are further improved by rolling.

The use of a thin film of electro-deposited cadmium was advocated by the Expanded Metal Company,[5] who claimed that on immersion in the aluminium bath, the cadmium volatilises, thus allowing alloying to begin.

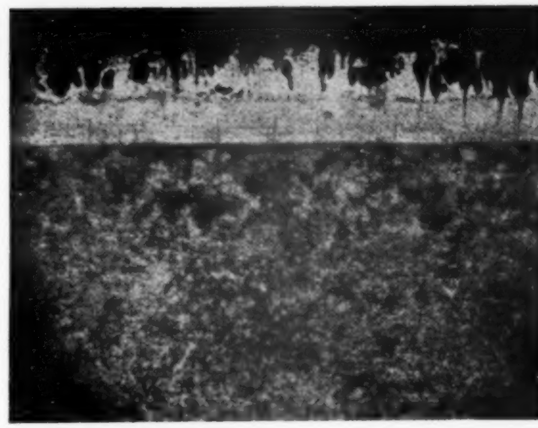

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Fig. 2.—Cross-section of calorised coating. Note alloy formation and outer aluminium. Excessive diffusion on heating to above 1,000° C. results in the disappearance of the outer layer with appreciable loss in anti-scaling properties. (Metallisation, Ltd.)

An appreciable amount of work on these lines has been carried out at The Sketty Hall Laboratories, of the British Iron and Steel Research Association[6] and the conclusion arrived at is that the results obtained with electro-deposited tin, zinc or cadmium are not at all consistent. Better results have been obtained by subjecting the strip or sheet to a pre-flash of copper[7]: this produces satisfactory coatings but, unfortunately, entails the gradual build-up of copper in the aluminium bath, with subsequent deleterious effects on the corrosion resisting properties of the coating. For heat-resisting purposes, this type of coating is considered to have many useful applications.

(*b*) *Pre-Fluxing Methods.* The functions of a flux in any hot-dipping process must be threefold :—

1. It must be capable of eliminating any oxide films formed on the steel base.
2. It must clean the surface of the bath in such a way that a reactive liquid metal phase is available at the moment of entry of the sheet or strip.
3. It must protect the ingoing material from further oxidation.

The relatively high temperatures involved and the tenacious nature of the oxide film on aluminium baths account for most of the difficulties associated with pre-fluxing methods, as proper selection and maintenance of the flux over a specific period involves many undesirable factors.

The most important patents covering the use of fluxes are those attributed to Nilsson.[8] The fluxes usually consist of alkali metal chlorides with appropriate additions of cryolite, the flux bath being maintained at a higher temperature than the metal dipping bath. The sheet to be coated is immersed for a fixed time and, with the molten flux still adhering to it, is quickly transferred to the molten aluminium.

Dellgren[9] designed a plant in which the flux bath—consisting of zinc chloride—and the aluminium bath are separately housed under the same air-tight container, through which hydrogen is passed. Individual articles to be coated are then transferred mechanically from one bath to the other and cooled in the reducing atmosphere.

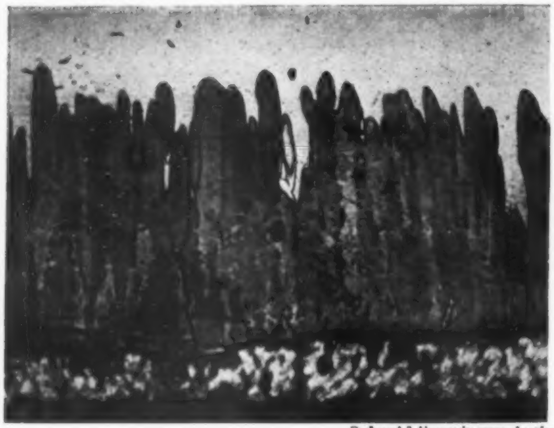

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Fig. 3.—Pure aluminium coating produced by a 30-second dip at 775° C. Deeply etched to reveal the complex nature of the alloy. ×400

Research at Sketty Hall has shown that fairly satisfactory coatings can be produced on these lines, but it must be emphasised that further work is necessary in the search for more reliable and efficient fluxes. These coatings suffer from appreciable porosity which appears to be the direct outcome of uncoated spots due to the accumulation of insoluble residues in the flux. Furthermore, iron pick-up in the flux is quite marked, and if the flux is not discarded in time, will lead to serious contamination of the aluminium bath. A most annoying feature normally associated with all hand-dipping processes is the frequent occurrence of pimples and blobs irregularly distributed over the surface of the sheet. Examination has shown that these blobs consist of aluminium trapped in a network of oxide.

The latest technique in the use of fluxes is based on the very simple control and ease of manipulation obtained by using electric salt-bath furnaces. Two furnaces are used, one containing the molten flux for pre-cleaning pickled stock, and the other the same flux upon the surface of which molten aluminium is floated. The temperature of the molten aluminium is closely controlled by suitable adjustment of the current flowing between two electrodes immersed in the flux. A. Di Guilio[10,11] points out that such a process has the very important advantage of employing a ceramic-lined pot, which gives immunity from bath contamination due to iron pick-up from the container.

A direct development of this process is the casting of aluminium on to steel.[10] The aforementioned method can be carried out to produce an aluminium coating on the steel, which whilst still hot, is transferred to a suitable mould, whereupon the immediate introduction of molten aluminium produces a satisfactory cast coating of aluminium on the steel. This makes the process virtually continuous.

(c) *Use of Protective Atmospheres.* Mention has already been made of the use of a protective atmosphere in conjunction with a fluxing process devised by Dellgren for coating individual articles. He further developed this work by constructing a plant for the continuous coating of strip[12], in which the strip is fed into a lead bath and up through a floating layer of molten aluminium held in a cylindrical container. The lead bath and aluminium pot are both enclosed in a furnace provided with an actively reducing atmosphere. On emerging from the molten aluminium, the strip is rapidly cooled in the gas before exposure to the air.

An important development was put forward by Fink.[13] In his process, the strip, after its preliminary treatment of degreasing and pickling, is passed into a bath of boric acid maintained at 600° C. The fluxed strip is then fed into a hydrogen furnace in which it attains a temperature of 900–1,000° C. In this temperature range, which is above the $\alpha - \gamma$ transformation, the steel base absorbs appreciable quantities of hydrogen, and the borate fluxing deposit fuses and forms on the strip a protective film which does not interfere with the hydrogen absorption. Surface decarburisation also takes place which, it is claimed, accelerates the alloying process in the metal bath. The strip passes into the molten aluminium, the surface of which is again protected from oxidation. The sheet surfaces, carbon-free, and containing absorbed hydrogen, are highly reactive and the period of immersion has to be carefully controlled. With this method, it is claimed that wire has been coated at the rate of 10–50 ft./min. It is also interesting to note that in spite of the treatment with hydrogen at high temperatures, it is said that the coated sheets show a remarkable ability for withstanding

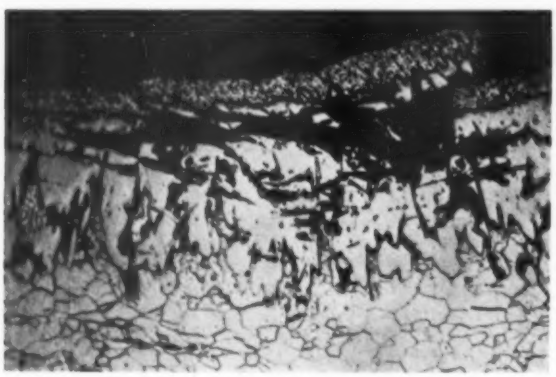

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Fig. 4a.—Behaviour of inner face in bend test. Coating : 1 minute at 725° C. ×300

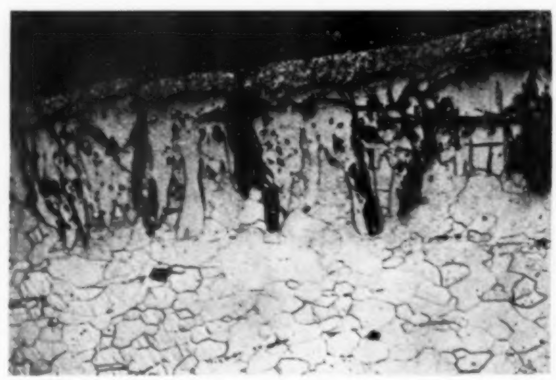

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Fig. 4b.—Behaviour of outer face in bend test. Coating : 1 minute at 725° C. ×300

normal working and bending operations. Recent trends in the hot-dip aluminising field have been mainly devoted to improving and maintaining the cleanliness of the strip emerging from the reducing atmosphere, thus producing a uniformly reactive surface capable of rapid attack when dipped in molten aluminium. Of these, the Alférieff and Sendzimir Processes require special mention.

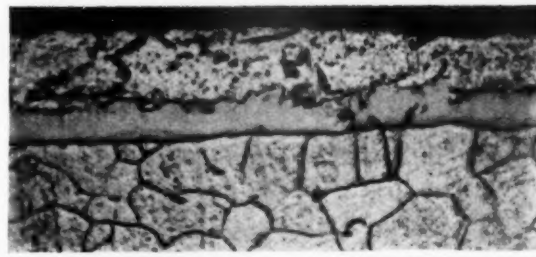
In 1942,[14] Alférieff gave an account of a process in which pre-heating of the sheet or strip is carried out in a triple-zone furnace incorporating automatic control. The strip is gradually brought up to annealing temperature under a slightly oxidising atmosphere before passing through a zone of maximum temperature, at which point controlled amounts of water vapour are injected to promote surface decarburization. Cooling is then carried out in a moisture-free atmosphere rich in nitrogen, and maintained until the steel base attains a temperature equal to that of the aluminium bath, which is electrically heated. Excellent results have been claimed for this process, but the latest information suggests that the plant is no longer in operation.

The American Rolling Mill Company[15] have adapted Sendzimir galvanising units for the production of hot-dipped aluminised coatings and the process, based on the deliberate oxidation and preheating of the strip prior to annealing in a cracked ammonia atmosphere, has been functioning successfully for the past ten years. Rolling oils and organic matter are removed in the preheating furnace by volatilisation and oxidation between 450° and 650° C., and a thin blue film of oxide is produced on the surface of the strip. The blued steel then passes into a reducing furnace where, under the action of hydrogen at 850–950° C., the oxidation products are entirely removed, resulting in an absolutely clean surface. Cooling to an appropriate temperature takes place under reducing conditions during the passage of the strip through a cooling chamber which extends to the surface of the molten aluminium.

Note on Bath Additions. The rapid reaction of molten aluminium with a perfectly clean steel base results in the formation of excessive amounts of a complex deep-rooted alloy, unless the period of immersion and the temperature are carefully controlled (Fig. 3). Even if the amount of alloy produced is not appreciable, it is brittle and hard in character and imposes a severe restriction on the workability of the coated sheet or strip (Figs. 4a and 4b). With the object of modifying the degree and nature of the alloying process, much intensive research has been carried out to examine the effect of adding alloying elements to the bath, and to-day, an excellent series of papers is available on this subject.

Alloying of the bath with zinc had been suggested by Dellgren[16] and Nilsson,[17] who claimed the preparation of coatings free from porosity and which showed distinctly better bending properties. The authors' investigations have shown that aluminium coatings containing zinc are not much different from pure aluminium coatings. The thickness of the coating is somewhat less and the proportion of alloy to outer coating smaller. Although the alloy layer is again relatively hard and brittle, a distinct improvement in bending properties is obtained.

The addition of 0·6% Si to the bath was suggested by Hoesch-koln Neuessen A.G.,[18] but the resulting coating improvement obtained is insignificant, compared with 6–7% Si addition employed in the Armco Aluminising



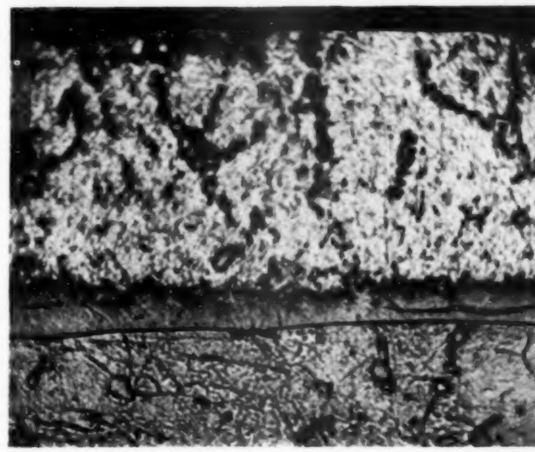


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Fig. 5a (top).—Armco aluminised sheet with excellent bending properties. ×1,000

Fig. 5b (bottom).—Laboratory coating (1 minute at 660° C.) with good bending properties. ×1,000

Patent, which employs the Sendzimir Process for pretreatment of strip, and to which reference has already been made. This Armco product has been examined by us and structurally similar coatings have been produced in the laboratory using a simple fluxing technique (Figs. 5a and 5b).

The beneficial influence of silicon in changing the nature and extent of the alloy layer results in the formation of thinner and more uniform coatings possessing much improved bending properties. Stroup and Purdy[19] have illustrated this impressive influence of silicon in graphic form, and the results obtained at Sketty Hall, shown in Fig. 6, seem to confirm this.

Gittings, Rowland and Mack[20] have examined the influence of adding a wide range of elements to an aluminium bath and it appears that only copper and beryllium are comparable to silicon in their effects.

Hodge and Smith[21] have investigated the effect of additions of rare earth metals to aluminium baths and point out that there are certain advantages in their use.

Cladding

Aluminium cladding of steel sheet or strip can be carried out either hot or cold. Early attempts were not successful owing to the formation of a brittle iron-aluminium alloy layer produced during annealing, but this was later overcome in Germany in a process known under the trade name of Feran.[22,23]

This manufacturing process is utilised by three German factories, and consists of the rolling together of

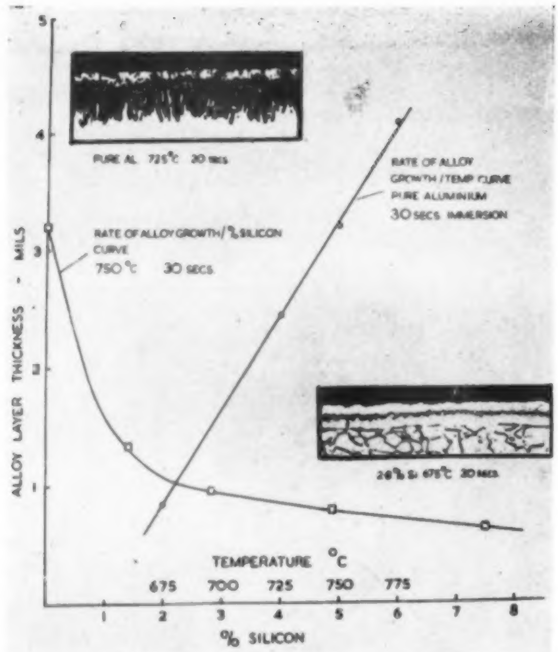

Fig. 6.—The influence of silicon on the nature and extent of the alloy layer.

separately prepared sheets of aluminium and steel. The aluminium sheet, containing a small percentage of silicon, is initially cold-rolled and roughened by wire brushes and then rolled in conjunction with the suitably prepared base in a two or four stand mill at a temperature of about 150° C. with maximum elongation of 40%. The laminated product is then further heat-treated at 540° C. when the growth of the alloy layer and degree of ductility are closely watched.

Stroup and Purdy mention that cladding may also take place in the bonding of clean surfaces of aluminium and steel with pressure at a temperature of 625° C.

Casting of Aluminium Around Steel

The continually increasing demands made upon aircraft engines during the recent war made it necessary to adopt some means of increasing and improving the cooling of such engines. As a direct result of this, the Fairchild Airplane Company introduced what is known to-day as the Al-Fin Process.[24,25] In this process, the steel or iron parts to be treated are first cleaned and then coated in an aluminium bath containing silicon. The coated part is immediately transferred to a sand or permanent mould and molten aluminium is poured around it to give the desired shape. This is done whilst the aluminium coating on the parts is still molten. Di Guilio has proposed the use of electric salt-baths in the carrying out of this process and reference has already been made to this under the section dealing with fluxes.

Electroplating

Electro-deposition of aluminium is carried out in fused salt mixtures of aluminium chloride with alkali chlorides,[26,27] or in organic electrolytes containing aluminium bromide.[28,29] High purity chemicals must be used in these processes as all metallic impurities below aluminium in the electromotive series interfere with the plating process. Bright and adherent coatings can be obtained this way and Fig. 7 shows a typical cross-section of an aluminium coating obtained from a bath of sodium and aluminium chloride. It is seen that this type of coating is free from iron-aluminium alloy layer and this property enhances the deep-drawing possibilities of such coated products.

Vapour Reaction Process

This method of producing aluminium rich surfaces on a steel base is known as the Martin Process,[30] whereby a surface layer of iron-aluminium alloy is produced by heating the base to about 930° C. in aluminium chloride vapour. The surface layers produced are exceedingly thin and, according to Stroup and Purdy, little or no protection is afforded to the base material.

Corrosion Resistance

Aluminium coatings have made prominent and significant advances in recent years and future developments are expected to be even greater. There is still much work to be done, as instanced by the corrosion testing already done in this country,[31] where it has been found that 1–3 mils thick Armco aluminised coatings behave rather differently from equivalent coatings of zinc. The behaviour in immersed conditions differs markedly with the nature of the water and it appears that the alumina film can be broken down by solutions high in chloride, resulting in the coating becoming anodic.

Lastly, to quote Dr. Hudson[32] on the subject of corrosion resistance of aluminised coatings, for certain purposes these coatings are preferable to galvanised coatings, although there are fields of usefulness for both, and for protection in industrial atmospheres over a

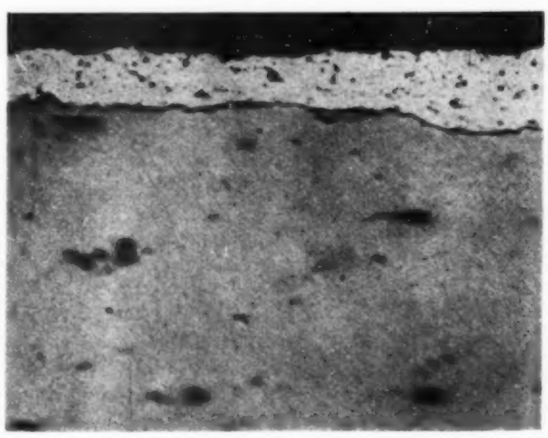

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Fig. 7.—Electroplated aluminium coating (Stroup and Purdy).

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Aluminium and Its Alloys in 1951

Some Aspects of Research and Technical Progress Reported

By E. Elliott, A.Met., A.I.M.

Information Officer, The Aluminium Development Association

Attention is drawn to published work reporting research and technical progress in the various aspects of the metallurgy of aluminium and its alloys, including extraction, founding, fabrication, constitution and properties.

IT is always difficult to appreciate a broad canvas when standing close to it, although such a viewpoint may be best for the details of a well-drawn picture. Our descendants will look back on the year of the second Great Festival and Exhibition, and will be able to get into much better perspective than we can the state of civilisation in 1951, and the stage reached in the advance of science and technology. In comparing 1951 with 1851, however, they are sure to note that each exhibition had its premier metal—cast iron in Victoria's reign, and aluminium 100 years later. As aluminium has been available as a commercial metal only during the last 60 years, it is obvious that its development has been very rapid, and it is well-known that this has been due to research and technical control to a degree previously unknown in the metallurgical world. West[1] has reviewed the evolution of aluminium over the past century and his article is a useful source of reference on production and development in alloys and applications.

That this process is continuing, and that technical and scientific advance is nowadays increasingly accompanied by discoveries and improvements in the engineering applications of aluminium and its alloys, is evident from a brief survey of some of the books, papers and articles which appeared last year. Material shortages are affecting aluminium and its alloys no less than other metals, and temporary frustrations are resulting, but present investigatory work is helping to ensure that the greatly increased supplies of metal which we are promised will be put to effective use.

Production

The directive from the United States Government to the American producers of virgin aluminium to consider the cost of moving their plants from their present locations, should this be rendered necessary by the shortage of hydro-electricity, has received considerable publicity. Aluminium has always been associated with water power, but, following the use of natural gas by the Aluminium Company of America, attention is being turned by that Company to power from brown coal.[2] This method of providing the necessary electrical energy is not, of course, new, being previously used in Germany, but it may appeal to other countries in a world short of harnessed water power and loath to invest the very considerable capital sums necessary for hydro-electric schemes.

The variability in composition and behaviour of bauxite occurring in one broad geographical location is brought out by Tiemann[3] in his comparison of aluminium ores from Jamaica and Hispaniola, both Caribbean islands with high plateaux where deposits are present in catchments in Tertiary limestone. The major part of the Jamaica bauxite is amenable to treatment by the American Bayer process, but those from Haiti, in the west of Hispaniola, require a modification of the European Bayer process, with high digestion temperatures and caustic concentrations. Some attention is devoted to the possibilities of the soda and soda-lime sintering processes, but together with the Pedersen process these are not considered suitable for Caribbean bauxites.

Despite the fact that bauxite is known to be present in various countries throughout the world in sufficient quantity to last the aluminium industry for a very considerable time, strategic considerations and transport difficulties ensure a continuing interest in the extraction of aluminium from other minerals. Fleischer and Glasser[4] have described experience with alumina produced from Maryvale alunite by the Kalunite process, from which they manufactured commercially acceptable aluminium on a fairly large scale. The chief drawbacks were found to be particle size—as the Kalunite alumina had both a coarse grain size and an excessive proportion of fines—and the presence of potash, both of which contributed to a worsening of the operating record of the pot line as compared with Bayer alumina.

The consistently good quality of secondary aluminium alloys in this country is well-known, but nevertheless Smith,[5] in replying to the discussion on his paper to the Annual Conference of the Institute of British Foundrymen, points out that the harm done in the past by inferior secondary alloys has still not been completely eradicated from the memories of engineers, and he suggests that to discontinue the use of the word "secondary" would be helpful. The paper is comprehensive and covers both the production and properties of casting alloys, taking the reader from the discarded casting or wrought product in the scrapyard to the ingot conforming to B.S.1490, and illustrating the close scientific control exercised throughout the process. A rather more primitive process has been used in some South Pacific islands for the recovery of metal from surplus aircraft, but despite difficulties arising from local conditions considerable success was attained, as described by Franz[6] in an interesting article which brings out the drawbacks of taking the process to the scrap instead of vice-versa.

Melting and Casting

While it is always useful to have available a range of articles from which to choose that most suited to the purpose in hand, too many varieties may constitute an embarrassment of riches, and it is, therefore, interesting to have summarised by Gauthner[7] the factors affecting the selection of a furnace for melting aluminium casting alloys. After reviewing the types available and their advantages and drawbacks, the author plumps for the stationary reverberatory furnace, and puts forward a good case for his choice, although no doubt devotees of other types would do the same for their own favourites. The subject is further treated in a later number of the same journal from the French point of view,[8] and the conclusion is reached that the low-frequency induction furnace should be used for making alloys from their constituents or other alloys, where the major portion of the charge is sound ingot metal and the remainder clean heavy process scrap, while the gas-fired reverberatory furnace is recommended for pure aluminium or for alloys from scrap of the same composition.

The alloy covered by the designation LM4-M in B.S.1490 is always associated with the name of Pritchard and the number D.T.D.424, and is much beloved of the aluminium founder, offering as it does a remarkable combination of properties. Two papers dealing with the material have been published during the year, by Lees and Glaisher[9] and by Fenn,[10] the latter to the meeting of the Institute of British Foundrymen already referred to. The former paper describes work at the British Non-Ferrous Metals Research Association on the effects on the properties of castings in LM4 of manufacturing procedure, grain size, gas content and heat treatment, and concludes that the origin of the alloy is largely a matter of indifference, provided that its composition and grain size are satisfactory, and its gas content suited to the particular work in hand. The beneficial effects of heat treatment on the mechanical properties of this alloy are now, of course, well-known. A point strongly made by Lees and Glaisher concerns the versatility of LM4, and this factor is the main subject of Fenn's paper, which includes some interesting pictures of castings produced by the three main methods, and a detailed account of the production by sand-casting of a rotary vacuum filter which weighed 10,800 lb. as cast and 7207 lb. when finished.

Lees also contributed a paper[11] to the I.B.F. Conference based on his work at the B.N.F.M.R.A. on the casting characteristics of aluminium alloys, and he lists interesting information regarding the behaviour of a number of alloys in relation to what he describes as the principal casting characteristics of a foundry alloy, namely founder's fluidity, susceptibility to hot tearing, susceptibility to internal shrinkage defects and susceptibility to external shrinkage defects. A further important factor in castings is grain size, and Cibula[12] has continued his study of methods of grain refinement, extending the scope of his work to include boron in addition to titanium. He is able to show that, with boron additions alone, the grain refining agent is aluminium boride, but, when both elements are added, nucleating particles of titanium boride are formed at very low concentrations of boron and titanium. Further, the use of both elements has the advantage over titanium alone that the alloys produced are more resistant to grain coarsening due to high casting temperatures, repeated melting and gravity segregation during solidification.

It seems particularly appropriate to terminate a section on melting and casting by reference to an account of a process which eliminates both these phases in the production of a solid metal or alloy. By compressing fine aluminium alloy scrap, Stern[13] claims to produce bars little, if any, inferior in properties to those made by conventional means, and so provides a quick and simple method of disposing of scrap which otherwise presents some problems.

Working

Following the undoubted success of its 1950 Symposium on the hot-working of non-ferrous metals, the Institute of Metals held in 1951 a similar meeting devoted to cold-working, and again the papers presented represent a mine of invaluable information on present thought and practice. The stage is set by Cook and Richards[14] in a paper on fundamental aspects of cold-working which summarises admirably modern thought on the subject, and enables the reader to assimilate the substance of a formidable list of literature references. Chisholm[15] deals at length with the lubricants used in cold-rolling, press-drawing, tube-drawing and wire-drawing, and suggests the best types for each process. The technique required in cold-rolling aluminium and its alloys on different types of mill is described by Davies,[16] and the interest of the paper is enhanced by the information it gives about ancillary handling equipment in addition to the rolling mill itself. Cleaver and Miller[17] contribute the paper on wire-drawing technique and equipment and trace developments from early times to the present day. The brief section on defects in wire is particularly useful to those not familiar with them. The last paper, on deep-drawing and pressing, is by Jevons[18] and he raises immediately questions of nomenclature which certainly require solution—what is the true difference between sheet and strip, and what is drawing as distinct from pressing? At the end of the paper appears a plea for greater collaboration between the supplier and user of sheet in the press shop, which will no doubt be echoed on both sides of the industry.

One of the problems to which Jevons refers is the occurrence of stretcher-strain markings, and this is a phenomenon to which a good deal of attention has been paid recently by the aluminium industry. Chadwick and Hooper[19] have investigated the effect in aluminium–3% magnesium alloy, and have concluded that the markings fall into two classes, the random variety which is more serious, and parallel bands at a definite angle to the direction of stretching. The former type may be avoided by keeping the grain size of the sheet between 0·5 and 0·8 mm., by a rolling pass followed by a low-temperature non-recrystallising anneal, or by temper-rolling fine-grained annealed sheet. This last treatment is reminiscent of that applied to deep-drawing steel, but it differs in that its effect does not disappear in a relatively short time.

It is interesting to read of the difficulties experienced by the makers of hot-breaking-down rolls for aluminium, and of their solution, and an article by a well-known firm of roll-makers,[20] describing procedures adopted, shows clear realisation by the manufacturers of what the rollers want, and indeed must have, if the sheet and strip produced is to be satisfactory to the consumer.

Mechanical working is necessary to shape metal to the form required, and also to render it homogeneous and to refine its structure, but many of the aluminium alloys require heat treatment to attain their maximum strength, and the mechanisms of annealing, solution treatment and precipitation treatment in a number of alloys have been discussed by Crowther.[21] He establishes clearly the requirements of industrial heat treatment which result from the theoretical considerations which he sets forth.

Joining

The day is long past when joining could with justice be described as the Achilles heel of aluminium technology but the volume of papers and articles on joining indicates the determination of research workers, metallurgists and engineers to spare no effort in solving the remaining problems. November, 1951, saw the holding of a Symposium on large joints by the Aluminium Development Association, and the papers presented and the discussion of them are expected to be published shortly.

Riveting continues to be an important method of joining aluminium and its alloys, with a fairly well defined distinction between technique for small and large rivets, about ½ in. diameter constituting the dividing line. Giddings[22] has provided a useful account of modern aircraft riveting, and it is interesting to note that one of his conclusions is that while in the immediate future this method of joining aircraft structure will continue to preponderate, its field of use will diminish and it will be replaced by bolted joints or even by machining components from the solid. Other competitors in aircraft joining are, of course, metal adhesives, and Moss[23] has surveyed their present applications in this and other fields. One of their particular merits is that such materials as rubber can be bonded to metal with relative ease, and an interesting example depicted is the rubber/aluminium racing plate, a horse-shoe which combines the virtues of lightness and strength with resilience on courses hardened by frost or sun.

The joining of large structures with aluminium alloy rivets presents problems due to the high power required for cold-driving, and the comparatively narrow hot-working temperature of the metal, and the work of Bailey and Brace[24] has therefore been received with considerable interest. They have established the maximum sizes of aluminium alloy rivets which may be closed with standard points, by available pneumatic hammers, and also suggested two alternative modifications in point shape to extend the range, namely a small pan point and a "recessed" point which may be adapted in accordance with the strength required. Some reference is made to the possibility of hot-driving.

Turning again to aircraft construction, one of the papers to the 1951 International Welding Congress at Oxford was on the subject of spot welding in the French aircraft industry, by Faguet.[25] This extensive account is full of useful detail about investigations by the French General Commission for the Study of Welding in Aircraft Construction, but the point which appears to have created most interest here is the claim that tetrachlorethylene, perhaps more commonly known as perchlorethylene, is a more efficient vapour degreasant than trichlorethylene. This view has not received full support from some sections in this country. Bushell[26] has provided a summary of spot and seam welding aluminium and its alloys, including machine ratings and cleaning and pickling procedures.

Argon-arc welding continues to be a focus for experimental work and the development of techniques, and a number of useful papers have been published. Binstead and West,[27] at the Welding Congress referred to above, presented an excellent account of recent experience with joining aluminium and its alloys by this method. The particular merit of the paper for the practical welder is that 22 different cases are described and illustrated, and details of welding current, voltage, electrode diameter, argon flow and welding speed are quoted. Further, the authors have not hesitated to consider the question of cost, a factor almost always difficult to ascertain from technical literature. Railton[28] also gives useful practical details in his description of the argon-arc welding of tubes, and a particularly interesting statement is that the switching out of the D.C. suppressors in the welding set enabled overhead welding to be carried out. Welding in this position has been considered hitherto to be difficult or impossible by conventional argon-arc, and no doubt this solution will receive further study. American practice in the construction of large aluminium tanks for the storage of chemicals has been described by Arnold[29] and he shows clearly the advantages in welding thick plate that the argon-arc process has over methods previously used. The details given in this account of the procedures adopted to ensure the most efficient use of welding combined with erection techniques remind the reader of the American skill in production engineering.

The most recent development in aluminium welding is, of course, the consumable-electrode inert-gas-shielded arc method known by a number of trade names here and in America. Herbst[30] has described this process in some detail as applied to aluminium and copper and their alloys, and to stainless steel. He offers suggestions for avoiding the weld porosity which has caused some trouble, and also considers the use of the method for building up worn aluminium alloy components, particularly pistons. The high speeds possible in consumable electrode welding, particularly if adapted to machine application, are brought out by Gross and Smith[31] in their account of the use of the process in aircraft welding of aluminium alloy and stainless steel. Speeds as high as 180 in. per minute are mentioned on aluminium-magnesium silicide alloy sheet 0·064 in. thick.

Urbain[32] has used a novel method to measure the tungsten consumption in the argon-arc welding of stainless steel and of aluminium. By means of the artificial radioactive tracer of tungsten, W.187, and autoradiography with exposure time of 20 hours, together with a Geiger-Muller counter, he has obtained rough figures for tungsten consumption and its distribution on the material being welded, in the weld, and as vapour. The total figure for aluminium is of the order of 25 micrograms per centimetre of weld. The work of the research team at Birmingham University on the cracking of welds in aluminium alloys has become well known, and a former member of the team, Moore,[33] has published two papers during the year on cracking in argon-arc and gas welds. The latter account puts forward methods for minimising the occurrence of cracks, including modification in alloy composition, the use of filler rods of special composition, and additions of titanium and boron.

A further paper presented to the Welding Congress mentioned above was by Herenguel and Hollard[34] on French studies on the weldability of aluminium-

magnesium alloys, mainly from the point of view of blistering and cracking. While the work on cracking is to some extent confirmatory of that of Pumphrey and Moore (above), that on blistering suggests the possibility that problems have only recently been solved in France which were overcome in this country some time ago, namely the manufacture of gas-free wrought aluminium-magnesium alloys.

A thoughtful article by Lancaster[35] on the fabrication of corrosion-resistant metals contains some information on the welding of aluminium, and the general comment by the author regarding the importance of the works metallurgist and the vital necessity for consultation at the design stage will surely command wide agreement. Bailey[36] has brought out clearly the factors affecting the design of aluminium articles which are made by the forming and joining of sheet, and he provides useful details concerning the reaction of several alloys to these processes and the best type of procedure to use under various conditions.

It is always a pleasure to record the advance of aluminium into a field not previously developed, and Lees'[37] account of the experiments which led up to the establishment of aluminium alloy stud welding is particularly welcome. The process is simple and provides a method of attaching studs which is rapid and gives excellent adhesion.

A welcome addition to the literature on non-ferrous welding is West's recently published book[38] which contains a large section devoted to the welding of aluminium and its alloys. Practical information is combined with a metallurgical background and it is hoped that it will be possible to keep the book up to date by sufficiently frequent revisions to keep pace with a rapidly developing branch of technology.

Constitution

The highest strength aluminium alloys are those based on zinc, magnesium and copper as major alloying elements, and at the present time they are regarded principally as materials for aircraft construction only, there being little experience of their use in general engineering. Although a good deal of research has been done on these alloys in the past, the systematic investigation reported by Cook, Chadwick and Muir[39] is most welcome, clearing up as it does many points previously obscure. After studying the freezing characteristics of alloys of this type, these workers selected a composition with a small eutectic content and this proved to have good working characteristics in addition to its superior casting qualities. Its composition was 6·5% zinc, 1·8% magnesium, 1·5% copper, 0·25% manganese and 0·25% chromium, and subsequent work was concentrated on the establishment of conditions for developing in this alloy the optimum combination of corrosion resistance, strength and ductility. Herenguel[40] has announced a new aluminium-zinc-magnesium alloy offering strengths in excess of 20 tons/sq. in. in the solution-treated condition, with good ductility. The material is stated to be readily weldable and to have high corrosion resistance and excellent formability.

Pratt and Raynor[41] have studied the intermetallic compounds in the alloys of aluminium and silicon with a number of other metals, and determined certain portions of the equilibrium diagrams for the systems aluminium-cobalt-silicon and aluminium-chromium-silicon. They include in their paper some intriguing illustrations of the compounds isolated. Fundamental research is als reported by Waldron,[42] concerned with the aluminium iron-cobalt-nickel system. His account includes a experimental method of investigating a peritect reaction which he suggests may prove to be of gener application.

The ageing characteristics of aluminium-copper alloy have been closely studied by Hardy,[43] who has relate the rise in hardness at various temperatures with th formation of Guinier-Preston zones, and put forward a explanation of the conditions favouring the attainmen of peak hardness. Arising from previous B.N.F.M.R.A. work on the susceptibility of aluminium-magnesium alloys to stress corrosion, Perryman and Brook[44] have investigated the mechanism of precipitation in these materials by metallographic and X-ray examination. The effect of additions of zinc in reducing precipitation at the grain boundaries was also studied.

The problem of the diffusion of copper into the cladding of metal of Duralumin-type sheets on repeated heat treatment or annealing is well known, together with its deleterious effect on corrosion resistance. Paic[45] has applied semi-micro radiography to the study of this phenomenon, and has shown that copper reaches the surface of cladding 0·15 mm. thick after about 80 minutes at 500° C., and that the presence of calcium in the cladding accelerates the process, contrary to some theories previously held.

Properties

The mode of deformation of aluminium has received considerable attention by investigators during 1951. Using specially prepared aluminium crystals of predetermined orientation, Cahn[46] has related the type of slip obtained on stretching aluminium with the degree of deformation and the temperature. Cross slip, on planes other than that subjected to the maximum shear-stress, was found always to maintain the same direction as the principal slip, but to vary in proportion with the conditions of testing. Chen and Mathewson[47] have also studied plastic deformation in single crystals of aluminium, and reached a number of conclusions regarding mechanism and direction of slip and the incidence of deformation bands. Still further observations on slip bands have been made by Brown,[48] who shows that high temperatures favour increase in slip at existing bands, rather than increase in the number of bands. The paper includes an excellent illustration of a slip-band photographed at ×25,000 magnification by the electron microscope. Wood[49] and his co-workers have continued their work on deformation, and have extended their theory of creep to show that a third stage, termed "boundary micro-flow," replaces, at low strain-rates and elevated temperatures, the previously-described "cell mechanism." They suggest that no further major change is likely to be observed as the rate of strain is further reduced.

In two articles in the same number of a journal, Servi and Grant[50] have analysed data on creep rates and rupture times for high purity and commercial purity aluminium. They note the existence of a transition range from low-temperature to high-temperature-type behaviour, and proceed to examine specimens metallographically to confirm their theories.

Sherby, Anderson and Dorn[51] describe experiments to ascertain the effects of alloying elements on the high temperature plastic properties of aluminium solid

solutions, and conclude that the mechanism is one of solid solution strengthening, restraining recovery and recrystallisation. They note the occurrence of a yield point in alloys aged after straining, and put it down to migrations of dislocations to the solute atoms. Turning to more practical considerations, McKeown and Lushey[52] have added to the information provided by the B.N.F. M.R.A. on the creep properties of various aluminium alloys. The alloys covered by this account include materials equivalent to HF17, LM14, LM4, LM10, LM5, LM7 and LM6.

The fatigue properties of aluminium and its alloys are receiving a good deal of attention at the present time, and Wood and Head[53] have made some interesting observations on the mechanism of fatigue, using aluminium to arrive at some of their conclusions. They state that cyclic stressing suppresses the disorientation of internal grain structure which is produced by static stressing, due to the lack of time for plastic deformation to occur. This theory accounts for some of the factors of fatigue failure since such an inhibition would, at rates of cyclic stressing above a critical rate, produce brittle fractures. Liu,[54] however, sees the mechanism of cyclic straining of a solution-treated Duralumin-type alloy as two distinct co-existing effects, namely, strain-hardening and deterioration, and shows that the effect of pre-compression is determined by its magnitude. Small amounts of pre-compression result in the preponderance of strain hardening during the first few cycles, whereas large amounts favour deterioration. With the aid of some elegant photomicrographs Forsyth,[55] using an aluminium–$\frac{1}{2}$% silver alloy, finds evidence of reaction to cyclic stressing by a recovery process associated with deformation bands and crystallites, and suggest that the crystallite formation at the roots of cracks may account for observed anomalies in the effect of stress concentrations on crack progress.

Until quite recently, super-purity aluminium was principally a laboratory metal, but its greater availability has revealed many applications for which it is eminently suited, and Lawrence[56] has reviewed the properties and uses of this interesting material. Alloying elements are known to have a considerable effect on the resistivity of pure aluminium, and Robinson and Dorn[57] have studied this effect for the elements Cu, Ge, Zn, Ag, Cd and Mg. The electrical resistivity was found to increase linearly with the atomic percentage of the solute atoms, and from this the authors arrive at a theory for the valency of aluminium in the metallic state. Hardy[58] has reported the tensile properties of heat-treated aluminium-copper-cadmium alloys in both wrought and cast form, and noted the beneficial effect of cadmium on strength and to some extent on corrosion resistance. Industrial use of such alloys is advocated.

Further information about alloy LM4 is provided by Scheuer, Williams and Wood[59] who have clearly demonstrated the interaction of the effect of silicon, copper and magnesium on the properties of the alloy, particularly the elongation. By keeping the magnesium low, there is considerable freedom in the proportions of copper and silicon which may be employed, but with magnesium over 0·25% no combination of silicon and copper gives the specified properties.

To read an article by Schapiro[60] on the airframe material of the future may engender pessimism amongst aluminium producers, for the author sees available aluminium alloys as inherently insufficiently strong and too susceptible to weakening by the temperatures generated by skin friction. However, he seems equally unenthusiastic about the alternatives—titanium alloys, magnesium alloys and stainless steel. Mackay and Dowdell[61] provide a formidable list of examples of metal failures in aircraft, and as this account appears in the same journal copy as Schapiro's, the general effect on the reader is cumulative. However, the authors of the latter paper do provide constructive suggestions for avoiding the failures described.

Corrosion

Edeleanu[62] has put forward a theory to account for the stress corrosion behaviour of aluminium-magnesium alloys which suggests that the most easily corrodible material is possibly not the β phase. The susceptibility to stress corrosion is thought to be at a maximum at an early stage in the ageing process, and to be due to the segregation of solute atoms at the grain boundaries. The method of progress of the corrosion is set forth. Also working with aluminium-magnesium alloys, but in this case containing 25% of the alloying element, Swain[63] has investigated their reactions with pure steam at elevated temperatures. The results are discussed in relation to the susceptibility of the LM10 type of alloy to metal mould reaction.

Although the use of high-strength aluminium alloy sheet clad with pure aluminium by rolling is well established, it is only recently that sprayed coatings of aluminium have been used for the protection of aluminium alloys. Champion[64] has described laboratory tests which support the value of such protection, and indicate that a purity of 99·5 to 99·6% aluminium is the optimum for the coating.

The plating of aluminium presents several special features and these have been summarised by Halls[65] together with the results of corrosion tests on plated specimens. Bryan[66] has published a note on the direct plating of nickel on to aluminium. Much work has been done in the recent past by the B.N.F.M.R.A. on the zincate process for plating on to aluminium, and Bailey[67] has provided a most interesting study, including a theory accounting for the adhesion obtained.

Applications

During the year a number of accounts have appeared concerned with advances in technique in the engineering application of aluminium, and several of them are well worth notice. A completely new method of barge construction[68] has been evolved in which extruded sections take the place of sheet, the term "composite plating" being applied to the process, and Latin[69] has considered the metallurgical factors in aluminium cable sheathing. The aluminium alloy hangars at London Airport[70] and their labour-saving method of construction have become famous, and much interest has been shown in the new aluminium alloy coaches for the London Transport Executive.[71]

This article began with a mention of the Festival of Britain, and would not be complete without a brief note of some accounts of aluminium in the South Bank and other Exhibitions. West[72] has considered the trends in modern design amongst both buildings and exhibits, and a number of smaller details[73] have also been described. A completely new roofing technique[74] was used for one of the buildings and the aluminium cladding panels for the "Skylon"[75] presented some unique planning and

tooling features, while construction of the Dome of Discovery has been fully described in a number of accounts published in 1950.

Standards

Finally, it is a great pleasure to record that the series of British Standards for aluminium and its alloys for general engineering purposes, envisaged during the last war, has been completed by the publication during the year of the standards for plate and for forgings stock, namely B.S.1477 and B.S.1472. It is now the task of all concerned to familiarise users with the alloy and temper nomenclature used in this series of standards.

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Rearmament Productivity Team

A TEAM of experts on Britain's rearmament programme is at present on a four week visit to the United States, studying American methods in use, both in Government arsenals and in industry, for the procurement, production, inspection and packaging of ammunition. It includes Brigadier E. M. Ransford, C.B.E. (Chief Inspector of Armaments, Ministry of Supply), as team leader, and Colonel W. P. Careless, D.S.O. (Military Assistant to the Deputy Controller of Supplies (Munitions), Ministry of Supply) as team secretary. Other members are senior engineer officers from the Ministry of Supply, representatives from five Government contractors and a foreman and operatives from the Royal Ordnance Factories.

The team will prepare a report for the series issued by the Anglo-American Council on Productivity with the technical assistance of the Mutual Security Agency (successor to the Economic Co-operation Administration). Attention will be specially directed to organisation, shop floor management, and to processes and techniques as affecting both production and inspection, particularly labour-saving devices. The training of supervisors and operatives, novel methods applicable to new types of ammunition and the satisfaction of contractual obligations in respect of quality will also be considered.

Progress in Welding Light Alloys

By P. T. Houldcroft,* B.Sc.Eng.(Met.)

An important step forward in the welding of light alloys was made when argon arc welding was introduced. The more recent development of a further type of gas shielded process using consumable electrodes is likely to have equally important consequences, and the greater part of this article is devoted to two variants of this process. Attention is also drawn to improved materials and the development of welding techniques.

INTEREST in the welding of light alloys has increased markedly of late, and this is, no doubt, a result of the considerable progress that has been made in the methods available for welding. In considering the advancement of light alloy welding it is interesting to examine three possible ways in which progress in this field can be made :

(*a*) the invention and further development of equipment or processes for welding ;

(*b*) the development of new or improved materials for welding, such as sheet and plate material, filler metal, electrodes and fluxes ;

(*c*) the improvement of welding techniques and the advancement of the state of knowledge regarding the application of processes and materials.

Most of the research and development work that has been carried out on the joining of light alloys falls into one of these categories, and there has been a significant difference between Great Britain and the U.S.A. in the emphasis of this work. In America more attention has been given to the development of processes, while in Great Britain considerable work has been done on the materials used in welding.

Prior to the development, about ten years ago in the U.S.A., of the gas shielded tungsten arc process, no really satisfactory process was available for the fusion welding of light alloys. It was natural that this development should occur in that country, since supplies of the inert gas helium were readily available. Although early work on this process was confined to the use of helium in welding magnesium alloys, it was not long before argon was being used to weld aluminium alloys. The introduction of argon arc welding was probably the most significant event in the history of light alloy welding, but the more recent development in the U.S.A. of the so-called "consumable electrode processes" promises to be of equal importance.

New Welding Processes

There are two processes of the "consumable electrode" type now in use in the U.S.A., and in both the arc is struck from the filler wire itself to the work-piece, the weld pool and arc column being shielded by a stream of inert gas. Although they are similar in this respect, these processes are otherwise quite different in both principle and application. The main difference between them is the way in which the arc length is held constant. In one process it is controlled by a device which varies the speed at which the filler wire is fed into the arc : this method of welding has been called the Controlled Arc Process.[1] The apparatus is similar to that employed in the "submerged-arc" welding of steel and, being an automatic head, it is used for mechanised welding.

In the second process, the filler wire is fed to the arc at a constant speed, but the welding current is chosen so that any tendency for the arc length to change is corrected by an electrical phenomenon inherent in the process. The arc length is maintained constant, not by controlling the wire feed speed, as in the controlled arc process, but by changes in the burn-off rate of the wire which occur naturally when the proper operating conditions are obtained. The arc length adjusts itself, therefore, and is independent of the distance between the nozzle of the equipment and the work-piece. This process, which has been called the Self-Adjusting Arc Process,[1] is suitable for manual operation. Apparatus for welding by the process is manufactured in America under the trade name of "Aircomatic" equipment. Although such equipment is not, as yet, available commercially in the United Kingdom, the British Welding Research Association has been investigating the process for some time, using apparatus constructed in the Association's laboratories.

The Self-Adjusting Arc Process

For welding by this process, a device is required which feeds wire of about $\frac{1}{16}$ in. diameter at a constant speed to a torch where contact is made with the welding current conductor. The filler wire which then carries the welding current emerges from a guide tube where it forms the positive pole of a D.C. arc to the work-piece. A stream of inert gas issues from a nozzle concentric with the guide tube, so that the welding area is protected from oxidation. Very high current densities of up to 100,000 amp./sq. in. are employed, and the thin filler wire must be fed to the arc at several hundred inches per minute. With an aluminium filler wire of $\frac{1}{16}$ in. diameter, satisfactory operating conditions are obtained when the current in amperes is approximately equal to the wire feed speed in inches per minute. The wire feed speeds employed vary from about 150 in./min. to 400 in./min. according to the welding current. It is essential to use a high current density with this process for two reasons :

(1) the metal transfer is then of the spray type and leaves the end of the wire with sufficient velocity to permit welding in all positions ;

(2) it is at high current densities that the arc becomes self adjusting.

The nature of this self-adjusting phenomenon is not yet fully understood, but it is known that with the

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1 Houldcroft, P. T., Hull, W. G., and Taylor, H. G. Symposium on the Welding and Riveting of Larger Aluminium Structures—The Aluminium Development Association. November, 1951.

Fig. 1. American equipment for the self-adjusting arc process, made by The Air Reduction Co.

conditions described above, and the drooping characteristics of the D.C. welding generator, the burn-off rate increases as the arc shortens, and vice-versa. Whether the arc shortens or lengthens depends on the difference between the wire feed speed and the burn-off rate. For a stable welding arc, the average burn-off rate must equal the wire feed speed, although it may be either above or below the wire feed speed at any particular instant. Thus, when the welding torch or gun is moved closer to the work, the arc is momentarily shortened. The burn-off rate then increases to exceed the wire feed speed and the arc burns back until the equilibrium arc length is once more established. The reverse series of events occur when the welding torch is moved away from the work. The self-adjusting phenomenon will operate only within a relatively narrow range of conditions, so that if the welding current is altered the wire feed speed must also be changed. For every setting of welding current, there is a small range of wire feed speed above which the arc length will decrease continuously so that the filler wire is eventually driven into the weld pool. At wire feed speeds below this critical range, the arc length increases continuously until the arc is broken. Variations of wire feed speed within the self-adjusting range can be used to alter the arc length, providing the current remains unaltered. It is usual in using the apparatus to select the desired current value and set the wire feed to approximately the speed required. An arc is then established and the arc length set to a convenient value by making a final adjustment of the feed speed. Once this has been done, the operator has no further control of arc length and has merely to point the nozzle of the torch in the right direction, and hold it at approximately the correct distance from the work, to ensure adequate protection of the heated metal by the shielding gas.

American Equipment

The type of apparatus used for welding by this process, comprising the torch or gun, the driving unit and control box and the contactor, is shown in Fig. 1. Wire is taken from a reel, housed in a covered container, by a pair of rollers and is pushed through a flexible tube to the welding gun. The inert gas is fed through a hose surrounding the wire feed tube and issues from the same nozzle as the filler wire. To begin welding, the filler wire is pushed forward so that it projects a short distance in front of the nozzle by operating an "inching" button on the torch. The trigger on the handle of the gun is then depressed and a relay starts the flow of gas and energises the welding circuit. When the arc is struck by brushing the end of the wire over the work, another relay brings the wire feed mechanism into operation. Since the burn-off is very high the wire feed drive must reach full speed in a fraction of a second or the arc would immediately become too long and fuse the end of the guide tube.

B.W.R.A. Apparatus

Two years ago the British Welding Research Association developed a self-adjusting arc unit for experimental work, shown in Fig. 2, in which the control circuit was simplified by the use of a magnetic clutch. The motor driving the wire feed rollers ran continuously at its operating speed. When the arc was struck, the welding current flowed through a solenoid which closed the

Fig. 2.—B.W.R.A. apparatus for the self-adjusting arc process.

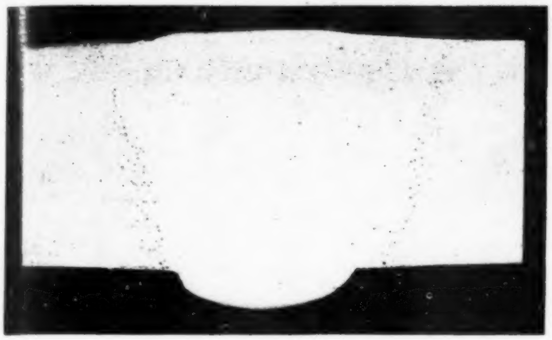

Fig. 3.—Fusion zone porosity in an argon arc weld in material with a high gas content.

clutch and connected the drive to the feed rollers. When the arc was broken the clutch dropped out and the drive was disconnected. The feed rollers were located in the torch itself and were driven by a flexible shaft connected to the clutch unit. As this arrangement pulled the wire to the torch, the problems of feeding the wire were simplified and it was also possible to use short lengths of wire for test purposes.

New Fields of Application

The ability to produce welds in all positions at high speed is one of the most attractive features of the self-adjusting arc process. Fillet welds can be made with ease at speeds far exceeding anything possible with the argon arc process, and thick plate can also be welded at higher speeds as the heat of the arc is transferred to the plate more effectively than in argon arc welding.

Because of these advantages, the self-adjusting arc process is expected to open new fields of application rather than compete with the argon arc process. The applications to which the process has been put already are discussed in detail in the literature.[2-9]

The Controlled Arc Process

This process is now coming into use in the U.S.A. and is particularly suitable for the mechanised welding of thick plate, although it has also been used for welding thin sheet at very high speeds.[10] The process differs from the self-adjusting arc method in that the arc length is controlled from the arc voltage by electronic or other means. Changes in the arc length are corrected by adjusting the speed at which the wire is fed. When the arc length is controlled by external means in this manner, a wider range of welding conditions can be employed than is possible with the self-adjusting arc process. Because the wire feed mechanism can be more robust in an automatic head, thicker filler wire can be employed and it is usual to use $\frac{1}{8}$ in. to $\frac{3}{16}$ in. diameter wire. With $\frac{1}{8}$ in. diameter filler wire it is possible to weld $\frac{1}{2}$ in. thick plate in a single pass at 18 in./min. This is about three times as fast as mechanised argon arc welding with a similar thickness of metal. The process has not yet been used industrially on a large scale, but it will be of increasing importance in the near future.

The application of welding to the joining of light alloys has been, and will continue to be, greatly extended by the developments in processes that have been described. Much still remains to be done to improve the equipment, but the basic form of the processes has been established.

Improved Materials

The development of materials is a second way in which progress in welding is made. A good example in this sphere is the work on the aluminium-magnesium alloys in which the B.W.R.A. has played a leading part. The occurrence of blistering and porosity in the heat affected zone of arc welds in these alloys is now well known. This porosity occurs in the severely heated zone, alongside welds in material with a high gas content. Special precautions can be adopted in casting the alloys to keep the gas content low, and this procedure will reduce porosity during welding. Since this type of porosity is developed by the heat of welding and is dependent on the thermal cycle which the material undergoes, its severity varies according to the welding process used. With argon arc welding, surface blistering may not be observed: it is not generally recognised, however, that fusion zone porosity can still occur with argon arc welding, the defect being confined to a narrow area alongside the weld. This effect is shown in the photomicrograph of the single pass weld in $\frac{1}{4}$ in. thick NP 6 material shown in Fig. 3. The material used here had a high gas content of about 0·5 ml. of hydrogen per 100 g. Fusion zone porosity of this type can reduce the ultimate tensile strength of the joint by up to 20%, with an accompanying premature failure in bend tests as shown in Fig. 4. If full advantage is to be taken of the excellent strength and ductility of the aluminium-magnesium alloys, it is obviously important to use welding quality plate.

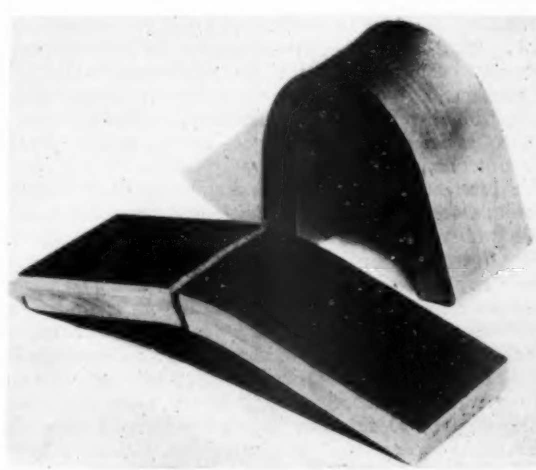

Fig. 4.—Transverse bend tests on argon arc welds in $\frac{1}{4}$ in. thick NP 6 material. Premature failure in metal with a high gas content.

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An argon arc weld in the N 6 alloy can have a U.T.S. of 17 tons/sq. in. if the filler metal is also N 6. The highest U.T.S. that can be expected from a joint in this alloy is about 18 tons/sq. in. as this is the strength of the annealed parent plate. By increasing the magnesium content of the filler wire, however, the strength of the weld metal itself can be raised. All weld metal tests on an aluminium –8% magnesium alloy deposit may give U.T.S. values of slightly over 19 tons/sq. in. with elongations of about 20%. The aluminium-magnesium alloys, then, are materials which have remarkable strength and ductility in the cast condition and show great promise as filler materials for general purposes.

Although excellent properties are obtained with the argon arc process, strengths as low as 7 tons/sq. in. U.T.S. are frequently obtained with metal arc welding. Recent investigations by the B.W.R.A. have shown that this low strength is not due entirely to the porosity which is a feature of this process. Weld metal deposited by the metal-arc process usually contains traces of sodium and lithium introduced from certain salts of these metals in the flux coating of the electrodes by reactions at the high temperature of the arc. By using experimental electrode coatings which contained neither sodium nor lithium salts the strength of welds in these alloys was increased by approximately 50%. Further work showed that although traces of sodium in the weld metal were definitely harmful to the properties of the weld, small amounts of lithium were apparently innocuous. To confirm the harmful effect of sodium, an argon arc weld was contaminated with sodium and its strength dropped from 17 tons/sq. in. to 11 tons/sq. in. Although the electrodes used did not have characteristics suitable for commercial work, these experiments have shown that it should be possible to produce electrodes giving higher-strength welds than are obtained at present. The development of an improved electrode with an aluminium-magnesium core wire would be of immediate value to industry.

The Development of Welding Techniques

A third way in which progress can be made is the advancement of welding techniques and knowledge of how to apply existing processes. Numerous ingenious adaptations of the argon arc process to mechanised welding have already been reported, and now that experience has been gained with the process, considerable progress has been made in the development of techniques for positional welding. Considerable work has yet to be done to devise suitable techniques for the self-adjusting and controlled arc processes.

An interesting development involving both a new technique and a new material is the recently introduced method of furnace and dip brazing, using brazing sheet. This process is being used to great advantage in a wide variety of applications in the U.S.A. It was a short step from the use of pre-placed brazing alloy in the form of wire, shims and washers to the use of sheet material actually coated with the brazing alloy. The sheet is made by applying an aluminium-silicon brazing alloy to the surface of the core material in the early stages of rolling, just as Duralumin type alloys are coated with aluminium for greater corrosion resistance. Quite complex parts can be stamped or pressed from brazing sheet, and to join the component parts of an assembly together it is only necessary to spray or paint them with flux and pass them through a furnace. If dip brazing is employed the flux painting operation is omitted. An accurate fit between the parts of the assembly is important, so that when the brazing alloy on the surface melts in the furnace it will flow into the joint by capillary attraction. Very uniform fillets are produced in this way and there is practically no limit to the complexity of the joints that can be made.[11] Joints can be made in materials of widely differing thicknesses which could not be made in any other way. It will be seen that this method of fabrication is ideally suited to mass production on a continuous basis and as brazing sheet is available in this country it is to be hoped that its wider use will be given serious consideration.

Now that satisfactory processes are available for welding light alloys, more attention can be given to work on materials. The introduction of new processes has been the most important factor in promoting progress in welding light alloys but only by the development of materials and techniques and a better knowledge of suitable applications can these processes be exploited to the full.

Acknowledgment

This paper is based on a lecture delivered recently to the West of Scotland branch of the Institute of Welding.

11 Clason, Clyde B. *The Welding Engineer*, **36**, 1951, November. pp. 33–35.

The Coating of Steel with Aluminium

Continued from page 74

period of five years, a coating corresponding to a thickness of 3 mils would be needed.

Acknowledgments

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Electrical Plant for the Metal Industries

CONTINUING our account of interesting electrical plant ordered for or commissioned in the metal industries last year, which commenced in our January issue with brief details of a number of English Electric installations, reference is made here to the activities in this field of The British Thompson Houston Co., Ltd., and The General Electric Co., Ltd.

Motor room of Morgan rod mill, showing sixteen B.T.H. D.C. motors and motor-generator set, at the Tremorfa Works, Cardiff, of Guest, Keen and Nettlefold (South Wales), Ltd.

The British Thompson Houston Co., Ltd.

Rolling Mill Drives.—The past year has seen the starting up of the Steel Company of Wales' great hot strip mill at Abbey Works, Port Talbot, and of the high-speed 5-stand tandem cold strip mill at Trostre, near Llanelly. The B.T.H. drive for the 80 in. 6-stand hot strip finishing mill at Abbey comprises six large D.C. motors totalling 28,000 h.p., supplied from a bank of mercury arc rectifiers of 21,000 kW capacity. The Trostre Mill, which will be used for rolling tinplate strip at a speed of 4,500 ft./min., is also driven by B.T.H. motors (totalling 19,150 h.p.) supplied from two synchronous motor-generator sets.

Among several other large drives put into operation was the first of three reversing mill drives at Round Oak Steel Works, Brierley Hill. This is for the new cogging mill and comprises a 4,000 h.p., 50/120-r.p.m. reversing D.C. motor supplied from a flywheel motor generator set.

During the year an order was received covering a drive for a 4-stand cold strip mill for Messrs. Lysaghts Works Proprietary, Ltd., Australia; this consists of three 4,000-h.p. and 2,000-h.p., and one 1,000-h.p. D.C. motors supplied from two 6,000 kW motor-generator sets. A contract is also in hand for the drive for a 4-high single stand foil mill by a 300-h.p., 535/1,070-r.p.m. main motor; and the Brightside Foundry and Engineering Co. placed an order for a 350-h.p., 350/840-r.p.m., 500-volt, D.C. motor, fed from a 280 kW mercury arc rectifier, to drive a 10 in. finishing mill.

Amongst other plant ordered may be mentioned two 1,250-h.p. D.C. motors with 2,000 kW mercury arc rectifier, for a billet mill; one 1,500-h.p., one 1,000-h.p., and two 350-h.p. induction motors for a seamless tube mill; one 350-h.p. induction motor for a tube reducing mill; and one 2,150-h.p. D.C. motor with synchronous motor-generator set for another seamless tube mill. This last mentioned is in addition to drives already in hand for the same customer, comprising one 2,150-h.p., D.C. motor and two 1,340-h.p., D.C. motors, with motor-generator set. Orders are also in hand for motors for tube mills and drawbenches and various auxiliary plant for rolling mills. Nearing completion at Trostre are drives for two 1,800 ft./min. coil preparation lines with photo-electric control.

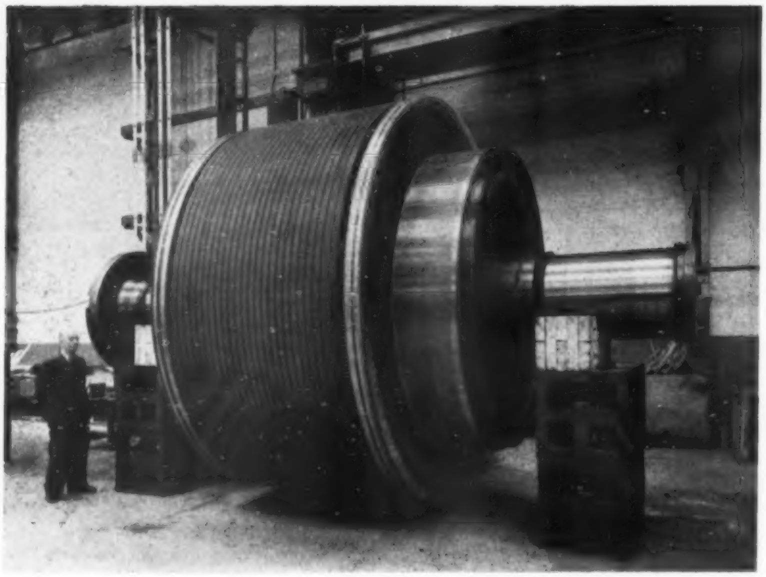
Arc-Furnaces.—Fifteen more amplidyne electrode-regulators have been installed or despatched during the past twelve months, and those installed range from an equipment for a 300 kVA furnace at the works of a machine-tool manufacturer at Coventry, to one for a 3,500 kVA furnace at a steelworks near Sheffield. B.T.H. has also supplied the furnace transformer, high-tension air-break contactor, and amplidyne electrode-regulator for a new 1,200 kVA furnace in Scotland. A further twelve home and export orders for amplidyne electrode-regulators are at present in hand.

Miscellaneous.—Considerable interest has been aroused by the W.1400 walking dragline—the largest in the world—which was commissioned last year. Built by Messrs. Ransomes and Rapier, Ltd., for Messrs. Stewarts and Lloyds, Ltd., this giant machine is used for stripping the overburden in the opencast mining of iron ore in Northamptonshire. All the electrical equipment, including a full Ward-Leonard control scheme requiring some 3,000 h.p. was manufactured by B.T.H.

For the heating of an Aetna single-sweep hot-tinning machine, a scheme using 'Pyrobar' heating elements, of a size considerably larger than has been manufactured previously, has been devised. A total of six heaters, each weighing 450 lb., have a loading of 180 kW at 420 volts, 3-phase. Such has been the success of the scheme that an order has been placed with B.T.H. for full electric heating equipment and automatic control gear for nine larger Aetna machines to be installed in the Trostre Works of the Steel Company of Wales during 1952.

The General Electric Co., Ltd.

Rolling Mills.—The 45 in. slabbing mill and the continuous hot strip mill at the Abbey Works of the



Armature of the G.E.C. 5,000 h.p. 700 volt cogging mill motor for Richard Thomas and Baldwins, Ltd., Redbourn.

Steel Company of Wales have been put into commission during the year, and the coil and sheet skin pass mills are nearing completion. At the Tinplate Works at Trostre, the pickling line is running and No. 1 temper mill will be completed early in 1952. Further orders for this project include 100 motors of various ratings for the ore preparation and sinter plant at Margam Works.

Developments at the Redbourn Works of Richard Thomas and Baldwins included the conversion of a 40 in. cogging mill from steam to electric drive. A 5,000-h.p. D.C. motor (12,500 peak h.p.) is used under Ward-Leonard control with cascade exciters; the Ward-Leonard Ilgner set is dynamically braked.

A single stand cold rolling steel strip mill supplied by Messrs. W. H. Robertson & Son, Ltd., of Bedford, to Devillez et Camion is in commission at Paliseul, Belgium. The G.E.C. provided the main and auxiliary mill motors, motor generator set, A.C. and D.C. control gear and the control desk. A further export order has been received from the Loewy Engineering Co., Ltd., for the electrical equipment for a cold strip mill being supplied to Austral Bronze, Ltd., Australia.

Among the orders received is a comprehensive contract with the Whitehead Iron and Steel Co., Ltd., Newport, Mon., for the electrical equipment for a cold strip mill. The contract includes the provision of the main motor, motor generator sets, switchgear, transformers and reactors.

Miscellaneous.—Equipment delivered overseas includes a third motor-driven blower for the Iron and Steel Corporation of South Africa, and a copper-nickel converter for the Rustenburg Platinum Mines, Ltd., also in South Africa. The latter is a duplicate of one forming part of a complete smelting plant, supplied in 1937 for smelting copper-nickel concentrates, and producing about 100 tons of copper-nickel in a 20-day campaign, working 20 hours a day. The equipment includes driving motors and very accurate control gear.

A number of interesting heat treatment furnace plants have also been installed but these will be dealt with in a composite article in the Heat Treatment Supplement in the May issue.

Expansion of Alumina Production Facilities in Jamaica

CANADIAN investment in the Caribbean area is to be augmented by at least $20,000,000 to provide large scale expansion of the bauxite-alumina facilities already under construction in the island of Jamaica. Aluminium Limited's new Jamaica alumina plant, the first in the Caribbean, is now having its planned capacity increased from 180 metric tons of alumina per day to 450 tons per day. The increase in capacity is required to provide more raw materials for Canada's rapidly expanding aluminium industry. Further enlargement of the plant to 670 metric tons per day is called for in the Company's plans as a successive development.

To service the alumina plant and handle export shipments, a deep-sea port will be created on the south coast of Jamaica. A 600-foot all-steel pier will be constructed at Old Harbour Bay with initial dredging operations to start immediately. Total investment by the Company in Jamaica may go as high as $40,000,000, including the cost of extensive agricultural projects initiated six years ago. The programme is being carried out by Jamaica Bauxites Limited, subsidiary of Aluminium Limited. All capital requirements are being provided by the parent company, with the exception of $6,700,000 towards the cost of the first-stage plant, which was loaned to Jamaica Bauxites Limited by the Economic Cooperation Administration (E.C.A.), now the Mutual Security Agency (M.S.A.). The loan is being repaid by aluminium shipments from Canada to the U.S. Government stockpile.

Production from the alumina plant will go chiefly to the new aluminium smelter being built by the Aluminum Company of Canada Limited, in British Columbia. This new west-coast smelter, with its estimated initial capacity of 83,000 metric tons of aluminium, will

create a considerable increase in Canada's requirements of raw materials. This has resulted in an expansion and acceleration of the construction programme in Jamaica. Savings of about 50% in shipping costs will be realised by extracting the alumina from the bauxite at its source, rather than shipping the ore itself to an alumina plant in North America.

First production of Jamaica alumina is expected to commence in the third quarter of 1952, while the greatly enlarged plant on which construction is well under way is scheduled to go into operation in late 1953. At the B.C. smelter, which will be ready for initial operation early in 1954, the alumina will be discharged from deep-sea vessels direct to storages and potlines 800 yards from the wharf.

The Company was the first to acquire bauxite properties in Jamaica and pioneered in geological exploration for the ore throughout the island. Tests were carried out originally in 1942 and were continued through the ensuing years, both in the field and in Canadian laboratories. 30,000 acres of land containing approximately 5,000 acres of bauxite deposits were purchased and an extensive agricultural and reafforestation scheme to raise the productivity of the remaining land has since been conducted. A stock of cattle suited to the Jamaican conditions is being bred and modern farming methods are being applied.

Mechanical Lifting of Tramrails

IT is common knowledge that scrap is most urgently needed by the British iron and steel industry and that a number of furnaces are shut down for lack of this vital raw material.

As has been repeatedly pointed out in the Press, there are many tens of thousands of tons of disused tram-rails embedded in roadways all over the country—the total for London, it is alleged, being some 60,000 tons. Such rails weigh about 100 lb. per yard and, cut to furnace sizes, make absolutely first-class heavy scrap of just the type of which the industry is in most need.

Of recent times economies have militated against the recovery of this valuable material. To up-lift the rails from the roadways by manual labour, using simple mechanical aids, is nowadays so expensive that the value of the recovered rails is but a small proportion of the cost of lifting and making good. Indeed, the true overall cost has been regarded as well nigh prohibitive, notwithstanding the increased price of scrap, and to many public authorities this has put the work out of court.

It will be obvious that this overall cost can be enormously reduced if the removal process can be speeded up and, further, that the steel industry must benefit from substantial and immediate deliveries of scrap which, so long as the old methods were regarded as the best, they had scarcely a chance of receiving.

With these considerations and certain other technical ones in mind, George Cohen Sons and Co., Ltd., the well-known Engineers and Scrap Merchants, have investigated the whole problem in the light of practical experience which, during the last two or three decades, has included the handling of hundreds of thousands of tons of tram-rails. They have now designed and produced a mechanical device, which is used in conjunction with a large excavator and allows the removal of the tramway track from the roadway at a speed approximately ten times faster than that attainable by the old methods.

It has been demonstrated that the first machine the firm are putting into use will deal with rather more than half a mile of rail per day—something exceeding a furlong of double track. It is believed that this rate can be substantially increased as operators become more skilled, and more machines can certainly be provided if necessary. But here a very important point arises. The re-surfacing of the road after the machines have done their jobs must keep pace with them—otherwise there is

the risk of serious and costly inconvenience to traffic. Therefore, if the maximum tonnage of scrap—an absolutely vital raw material—is to reach the steelworks without a day's avoidable delay, means must be found of ensuring that the machines are not, in effect, retarded by any lack of speed or efficiency in the re-surfacing of the roadway behind them.

Warren Research Fund Commitee

THE WARREN RESEARCH FUND COMMITTEE of the Royal Society is initiating a programme of research on low pressure gaseous discharge and for this purpose has appointed the following research workers for a period of three years :—

MR. L. W. KERR, to work at the University of Birmingham ;

MR. C. G. MORGAN, to work at University College, Swansea.

DR. E. J. SMITH, to work at University College, London.

A grant has also been made to MR. J. M. SOMERVILLE of New England University College, Armidale, Australia, to enable him to work for one year at University College, Swansea.

Immersion Pyrometry in the Steel Industry

By Frances Mortimer, B.A.

British Iron and Steel Research Association.

The increasing bath temperatures resulting from the adoption of basic furnace roofs, and from the use of oxygen-blowing, are making fresh demands on those responsible for immersion pyrometry developments. In this brief general account of the subject reference is made to present practice and future trends.

HIGH temperature measurement presents many problems, particularly in the glass, iron, steel and chemical industries, where measurements must be made speedily under severe conditions of mechanical loading and chemical attack. Many of these problems were solved by scientific research between the wars, and the results were almost immediately applied in industry. This was reflected in the steel industry of Great Britain in the development of immersion pyrometry for measuring the temperature of molten steel. This interest in more precise knowledge and control of bath temperatures in the steelmaking furnace, which in turn permits greater and more consistent control of steel quality, may be traced to the need for increased production and better furnace life. The fuel and raw material shortage, which has become increasingly a problem in this industry, has also helped to stimulate recent research on the subject.

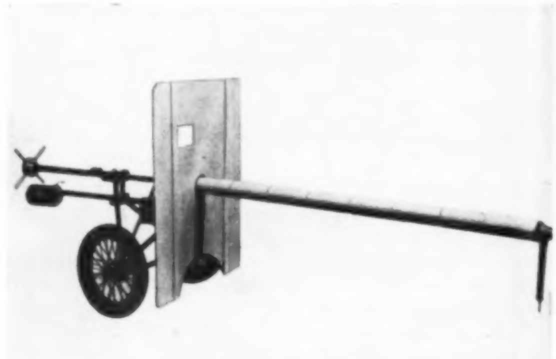


Fig. 1.—Trolley type immersion pyrometer designed for use in the larger open-hearth furnaces.

The Need for Temperature Measurement

The steel melter needs to know the temperature of the steel he is making for a variety of reasons. In the first place he has to decide the correct time for feeding ore, because of the relationship between the carbon content and the temperature of the bath. The carbon content governs the type of steel which is being made : a rimming steel, for instance, which is used for sheet, must be low in carbon and hence requires a high temperature ; on the other hand, a high carbon or hard steel will generally require less heat.

The refining process involves the simultaneous reduction of the carbon content, by oxidation, and the increase of the temperature. When the melter introduces such ingredients as mill scale or iron ore into the bath, the act of feeding cools the bath as well as releasing the carbon in the form of carbon monoxide gas, so that he must keep careful watch on the temperature at the same time as he checks the fall in carbon. If he proceeds too quickly and overfeeds the bath, especially in the early stages of refining, it will go off the boil. If this happens, and the furnace goes 'dead,' it is very difficult to get it going again, and the refining speed and fuel consumption suffer accordingly. Broadly speaking, the lower the carbon content of the bath, the higher the temperature must be, so that the melter must constantly watch the carbon/temperature ratio, as recorded by his instruments, and avoid any deviation from the recommended standard.

A knowledge of bath temperature is also important because of its indirect effect on the life of the refractories. While there are radiation pyrometers specially designed to show roof temperature, it is only by knowing the exact temperature of the bath that the steelmaker can maintain the optimum temperature for refining without risking needless wear on the refractories. If he lets the furnace reach a higher temperature than necessary, or, by overfeeding, forces it to go off the boil and so has to risk an intense flame to get it back again, the furnace life will be shortened. High refining temperatures are generally about 1,650° C. and the limit of silica refractories (which are used because they are cheaper) not more than 1,680° C. The penalty for ignoring this safety margin is loss of working time and replacement costs.

A knowledge of temperature conditions, by making it possible for the steelmaker to control the viscosity of the molten metal, also helps him to ensure the correct conditions for teeming. This leads to considerable savings by reduction in the amount of skull left in the ladle, reduces sticking on bottom plates and moulds, and helps to decrease the time spent in dressing the ingots.

Higher Operating Temperatures

The measurement of liquid steel temperature has become increasingly important in recent years, as the temperature of the steelmaking furnace has been increased by such developments as oxygen and air lancing, and the growing use of basic bricks in roof construction. The instruments now in use will cover a range of steelmaking temperatures up to 1,700° C., but already the temperature of the steel bath is raised to nearly 1,900° C. when the oxygen lance is used in an electric arc furnace, and steel temperatures above 2,000° C. are not unknown. While it is felt that at these temperatures the steel melter is more interested in cooling down his furnace than in knowing the exact temperature, the demand is growing for instruments capable of measuring temperatures up to 1,860° C. and work is now

Fig. 2.—Lighter hand-manipulated immersion pyrometers.

proceeding along these lines. E. J. Burton and J. P. Simons of the B.I.S.R.A. Physics Department, for instance, are now working on a tungsten-molybdenum thermocouple, the outside limit of which is well over 2,000° C. In the laboratory, tests have been made up to 1,900° C. and a temperature of 1,840° C. has been measured in an electric arc furnace after an oxygen blow. As the refractory manufacturers catch up with this trend, this limit may be exceeded. Research workers are even now pointing out that in 1936 the demand was for thermocouples capable of measuring temperatures up to 1,660° C. and it was then supposed that this range would never be further extended.

The thermocouple, which is a device depending on the e.m.f. developed between two wires of different metals, is the basis for this particular technique of liquid steel measurement. The voltage generated when the contact end of the wires is heated, is proportional to the difference in temperature between the hot junction end and the cold end, and can be measured by means of a millivoltmeter or potentiometer.

In the U.S.A., where the steelmaker can afford to be less careful because of the high quality of the raw materials he is dealing with, radiation sensitive devices have been used rather more widely than the thermocouple in immersion pyrometry. Despite the fact that these devices are less expensive, reports indicate that the much greater accuracy of the British device has won over many American firms in recent years.

In Britain, where the outlook is toward poorer ores and poorer fuels, improved technical resources are an absolute necessity. This work on immersion pyrometry goes back to 1929 when a liquid steel temperature sub-committee was set up under the auspices of the Iron and Steel Industrial Research Council to consider and report on existing methods of measuring liquid steel temperature. In 1936, the British Iron and Steel Federation granted financial support toward the development of a thermocouple for taking readings directly in the furnace or ladle. Attention was soon concentrated on the platinum thermocouple and, in 1937, the sub-committee put forward several designs for the "routine measurement of steel temperatures in open-hearth and electric furnaces, whether of the acid or basic types, and also for such measurements in the launder, ladle, trough and mould." They found that the various forms of the instrument could be handled with a little practice and were not unduly expensive, though running costs depended on the particular type. Immersion pyrometry is now established as routine practice in most steelworks in this country.

Types of Pyrometer

There are several different types of immersion pyrometer, trolley type models (Fig. 1), built expressly for the larger open hearth furnaces, and lighter hand-manipulated models for use on the smaller open-hearth, electric-arc and high-frequency induction furnaces (Fig. 2). There is also a model designed for use where space is limited, and which can be permanently attached to the furnace (Fig. 3).

The design of the thermocouple arm is simple. It consists of a steel tube through which the thermocouple wires pass, forming a junction at one end and wound into a reserve reel at the cool end. One wire is usually platinum and the other an alloy of platinum with 13% rhodium, though platinum-rhodium thermocouples with rhodium contents up to 40% have been used to measure temperatures up to 1,900° C. in oxygen-blown steel. The reserve reel is used to renew the hot junction when necessary, usually after 15 to 25 immersions. The last inch or so of the wires is clipped and the junction remade from the additional wire which is pulled through. Fire-clay or similar material is used to insulate the wires from the tube and from each other. Twin bore silica insulators are provided near the hot junction as a rule, though alumina reduces the chance of silica contamination of the couple. The external insulation varies according to conditions in the bath, the end block being covered by a graphite sleeve or mild steel cylinder, or a steel cylinder with a graphite covering. The couple is

protected from slag, steel and fumes by a thin silica sheath which must be replaced after each immersion. This can be packed in previously ignited asbestos string or wool and inserted over the couple and into the end block. Fused alumina dipping tubes, coated with alumina cement to minimise thermal shock, are used in place of these silica sheaths when the pyrometers are adapted for continuous measurement, i.e. for periods up to two hours, of the steel temperatures in high frequency furnaces.

Compensating leads connect the reel box to the indicator or recorder. The millivoltmeter type is suitable with short couples or where there is little variation in external resistance. Potentiometric measurements, however, are now most widely used, and as automatic recorders they are ideal, because they cut out the human element and give a permanent record.

Contamination

The most serious problem in the use of these instruments is contamination, as this determines the accuracy of the measurement as well as the life of the couple. The main cause of contamination has been shown to be the simultaneous presence of silicon, carbon and sulphur. These cause the formation of platinum silicide which alters the constant of the couple leading to early embrittlement and failure. This particular cause of contamination can be reduced to a minimum by avoiding the simultaneous presence of these elements, for instance by replacing the graphite end blocks by steel or by using alumina insulators instead of silica. Scrupulous cleanliness and care in the assembly and use of all parts of the instrument will help reduce the effects of the sulphur in oil or grease or reducing gases. Dirty hands are a frequent source of contamination.

Thus it is very necessary to have some means available to check couples and measuring instruments. So far, there is no method of calibration in common use, but several techniques have been developed which give fairly satisfactory results. A workshop method is to check simultaneous or consecutive immersions against a standard couple using the same measuring instrument. Another technique which is employed at a French works

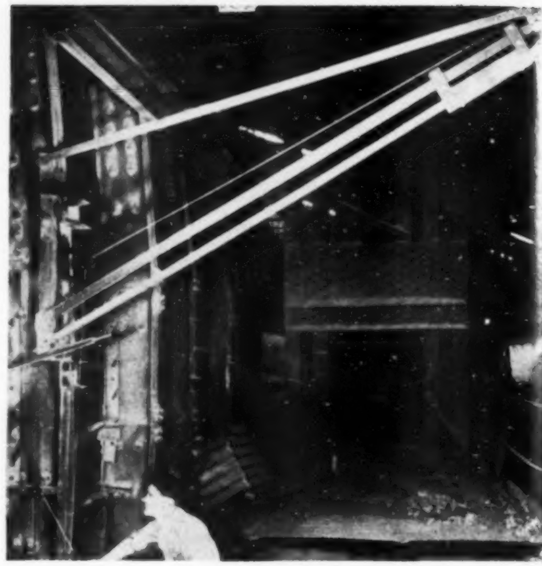


Fig. 3.—Immersion pyrometer, designed for use where space is limited, which can be permanently attached to the furnace.

makes use of palladium which has a known melting point of 1,552° C. When a few strands of this metal are wound around the hot junction and the couple immersed in the furnace bath at about 1,570° C., there should be a break in the heating curve at 1,552° C. Unfortunately this arrest point is not always clearly defined and the couple is destroyed in the process. Both these methods can be used under service conditions, and allow for any defect along the wire which might be affected by a temperature gradient. A further method is being developed by Burton and Simons in the B.I.S.R.A. Physics Department. This provides for a uniform temperature zone in a small furnace situated on the stage so that the suspect thermocouple can be checked against a standard. This calibration furnace, however, is still in the process of development.

Accommodation for Scottish Representatives

In response to the many requests received for office facilities, The Engineering Centre has now arranged accommodation for a limited number of engineering firms' Agents or Representatives.

An area of approximately 1,000 sq. ft. is being furnished with tables, desks, private lockers and telephone booths. The total number of participants will be limited to approximately 20. The facilities offered include the use of the Centre's telephone numbers and address for the receipt of mail, messages, etc. Letter typing can be undertaken either from copy or by dictation, and the Centre's catalogue library and information service may be used in Glasgow.

This development is the Centre's latest addition to the many services which it offers to the engineering industry, and although a weekly charge is made, it will be found to compare very favourably with the normal charges for accommodation and secretarial services. It is thought that the above information may be of interest to firms who are contemplating the appointment of a Scottish Representative.

Correction

A New Version of "Strength of Materials"

We regret that two typographical errors occurred in Dr. A. C. Vivian's article, "A New Version of Strength of Materials," which appeared in our January issue. Will readers please note the following corrections :—

Page 31. The expression at the beginning of the second line of the footnote should read $(A_0 - A)/A$.

Page 37. Line 6 should read $100\ (A_0 - A)/A$.

Foundry Films Shown

Following a meeting of Senior Representatives and the Executive Staff of Foundry Services, Ltd., held at Nechells, Birmingham, last month, the four films on gating systems, produced by the Research Department of the U.S. Navy, were shown.

NEWS AND ANNOUNCEMENTS

The Institute of Metals

Election to the Council

THE following members have been elected to offices on the Council of the Institute of Metals for the year 1952–53, and will take office on March 25th next :—

President : Dr. C. J. SMITHELLS, M.C., Director of Research, The British Aluminium Co., Ltd.

Vice-Presidents : Mr. G. L. BAILEY, C.B.E., M.Sc., Director, British Non-Ferrous Metals Research Association ; Dr. S. F. DOREY, C.B.E., Wh.Ex., F.R.S., Chief Engineer Surveyor, Lloyd's Register of Shipping.

Honorary Treasurer : Mr. E. H. JONES, Director and General Manager (Bristol), Capper Pass & Son, Ltd.

Ordinary Members of Council : Mr. ALFRED BAER, Vice-Chairman, The Consolidated Zinc Corporation, Ltd. ; Mr. N. I. BOND-WILLIAMS, B.Sc., Chairman and Managing Director, Aston Chain and Hook Co., Ltd. ; Dr. N. P. INGLIS, M.Eng., Research Director, Metals Division, Imperial Chemical Industries, Ltd. ; Dr. IVOR JENKINS, Chief Metallurgist, Research Laboratories, The General Electric Co., Ltd. ; Dr. A. G. RAMSAY, B.Sc., Director, The Mond Nickel Co., Ltd., and Works Manager of the Refinery, Clydach ; Dr. H. SUTTON, Director of Research and Development, Aircraft Materials, Ministry of Supply ; Major P. LITHERLAND TEED, A.R.S.M., Deputy Chief of Aeronautical Research and Development, Vickers-Armstrongs, Ltd. ; and Mr. W. J. THOMAS, Assistant Managing Director, The British Aluminium Company, Ltd.

Students Essay Prize Competition 1952

THE Council of the Institute will present, annually, two prizes of twenty guineas each for the best essays submitted in accordance with the regulations set out below. Each prize will be in the form of ten guineas in money and ten guineas in scientific, technical or other appropriate types of books, to be selected by the prizewinner. If of sufficient merit, a prize-winning essay may be published in the Institute's " Bulletin " or selected for reading before a Local Section.

REGULATIONS

1. *Eligibility*.—The competition is open to all Student Members of the Institute, and to all Associate Members of Local Sections who are eligible for Student Membership of the Institute provided that both are within the normal age limits for Student Membership, *viz.*, 17 to 25 years. A prizewinner will be ineligible to compete in the competition in the year subsequent to that in which he or she submitted a winning essay.

2. *Language*.—Essays must be submitted in English.

3. *Length*.—Essays should be 2,500–3,500 words long and must not exceed 3,500 words. They must be submitted in typewritten form—double-line spacing.

4. *Subject*.—For the 1952 competition candidates may select a subject which comes under one or other of the following two headings. One prize will be given under each subject.

(i) " Non-Ferrous Foundry Practice."

(ii) " Metallography in Industry."

The subject matter should be logically presented, in good English, and should have a metallurgical content to impress the adjudicators by soundness, exercise of critical faculty, and originality of approach.

In each subject no prize will be awarded if the essays do not, in the opinion of the adjudicators, reach the requisite standard.

5. *Method of Submission*.—Each entry must be submitted to The Secretary, The Institute of Metals, 4, Grosvenor Gardens, London, S.W.1, not later than Monday, 19th May, 1952, and must be accompanied by a certificate, signed by the entrant, that the essay itself is entirely his or her own work, that it has not, in the form in which it is sent, been submitted for any other competition, and clearly stating what (if any) drawings, photographs, etc., have been prepared on his or her behalf.

Award of Medals

THE Council of the Institute has made the following awards of medals for 1952 :—

The Institute of Metals (Platinum) Medal to MR. W. S. ROBSON, until recently President of the Consolidated Zinc Corporation, Ltd., in recognition of his outstanding services to the non-ferrous metal industries in developing the Australian zinc-lead industry and the British zinc industry.

The Rosenhain Medal to Professor A. GUINIER, Conservatoire National des Arts et Métiers, Paris, in recognition of his outstanding contributions in the field of physical metallurgy, particularly in connection with precipitation phenomena.

The W. H. A. Robertson Medal to MR. C. E. DAVIES, for his paper on " The Cold-Rolling of Non-Ferrous Metals in Sheet and Strip Form," published in the *Journal*, 1951, vol. 78, pp. 501–536.

1952 May Lecture

THE 1952 May Lecture to the Institute will be delivered by Dr. J. J. P. Staudinger, on " The Place of Plastics in the Order of Matter." The meeting will be held in the Lecture Theatre of the Royal Institution, Albemarle Street, London, W.1, on Monday, March 24th, at 6 p.m. Visitors will be welcome ; tickets are not required.

Steel Allocations

Amendments to Scheme

JUST before the iron and steel distribution scheme came into operation on February 4th, the Minister of Supply (Mr. Duncan Sandys) made an Order authorising a number of adjustments. They are as follows :—

(*a*) Consumers may use the stock held at the close of February 3rd, 1952, for a purpose for which they hold a control authorisation.

(*b*) The holder of a control authorisation may send material out on loan to be worked up for him. This amendment is designed to cover the " free-issue contract " customary in some trades for outside processing of material.

(*c*) Two new items—wire rod reinforcement fabric mesh, and wire reinforcement fabric mesh—are added to the list of controlled forms of steel.

(*d*) The list of Small Quantities Exemptions has been extended to permit the purchase without licence of 5 cwt. a month of these items, and also one ton a month of "Large Spring."

The Order is the Iron and Steel Distribution (Amendment No. 1) Order, 1952, (S.I. 1952, No. 172), and is obtainable from the Stationery Office, (price 4d.). An "Amendment No. 1, February 1952" to the "Notes for Consumers, January 1952" is also being issued by the Stationery Office.

The Ministry of Supply also announces that, as from April 1st, 1952, the separate allocation of non-alloy steel sheet will be abandoned, and that, thereafter, such steel sheet will, for allocation purposes, be merged in general non-alloy steel. Customers will be free to decide for themselves, within their total authorised tonnage, how much they wish to order in the form of non-alloy sheet steel and how much in the form of other non-alloy steel (other than tin plate, terneplate and black plate, which will remain subject to separate allocation as at present). Outstanding sheet allocations on forms M (Sheets) will still be valid with their legal requirements unchanged.

New Solder Factory

H. J. ENTHOVEN & SONS, LTD., will open a new section of their Solder Factory at Croydon early this year. This extension has been necessitated by the increased demand for their products by both home and foreign

The new factory in course of erection

consumers. The official opening date has not yet been fixed but the Company expects to start production in the new factory early in March. The new factory floor area will represent an increase of nearly 100% on the existing area.

The output will consist mainly of "Superspeed," the Enthoven activated rosin cored solder, chiefly in the usual wire form, but provision has also been made to increase production capacity for cored ribbon. The new plant will also cater for other solder specialities, including, for example, coloured cored solder, which has been found of considerable value in the electrical industry, lamp solder and various soldering fluxes. Possibly the most interesting single item of new plant which has already been installed in the partially completed building is a 400-ton Fielding and Platt Extrusion Press for cored solder, many features of which are the result of collaboration between Enthoven's and the suppliers.

Personal News

MR. T. POWELL, General Manager and Director of British Electro Metallurgical Company Limited, has been appointed Managing Director of the Company.

MR. G. R. BALL, Vice-President, General Manager and Director of the Bank of Montreal, has been appointed to the Board of The International Nickel Company of Canada Limited.

THE United Steel Companies Limited announce that MR. E. E. INGLETON has been appointed Works Manager of Yorkshire Engine Company Limited, and that MR. C. E. EDWARDS, Commercial Manager of their Appleby-Frodingham Branch, has been appointed a Director of the Appleby-Frodingham Steel Company.

MR. F. GEORGE, who was a Director of Zirconal Limited for four years, has severed his connection with that Company and joined Refractory Mouldings and Castings Limited as a Director.

MR. F. G. WOOLLARD, of the Birmingham Aluminium Casting (1903) Company Limited, has recently been elected as Chairman of the Council of the Zinc Alloy Die Casters Association for 1952-53. He will be assisted by MR. J. W. CARTLIDGE, of Dyson & Company, Enfield (1919) Limited, who as retiring Chairman assumes the office of Deputy Chairman.

MR. K. R. GREEN has been appointed Sales Manager, Scientific and Industrial Products, of Sunvic Controls Limited. Mr. Green, who joined the Company early in 1951 as an Application Engineer, has had extensive experience in the instrument industry.

FOLLOWING upon the resignation of MR. H. NIELSEN, MR. E. C. DAVIES has been appointed Manager of the Heavy Plant section of the Engineering Sales Department of The General Electric Company Limited, with MR. G. F. J. MORGAN as Assistant Manager.

MR. R. P. TOWNDROW, Manager of Clyde Iron Works, Tollcross, of Colvilles Limited, has been appointed an Executive Director of the Company.

SIR ANDREW MCCANCE has accepted an invitation to be Chairman of the Mechanical Engineering Research Board of the Department of Scientific and Industrial Research, in succession to Sir Henry Guy.

MR. C. GOTELEE has been appointed Joint Managing Director with MR. I. LLOYD of the Expert Tool and Case Hardening Company Limited. MR. H. CHERRY, Managing Director of a subsidiary, Waddells Stratford Steel Equipment Company Limited, has joined the Board of the parent Company.

MR. J. E. MALAM has been appointed a Director of Murex Limited.

MR. L. W. GWYN, Vice-Chairman of the Local Directors of Newton, Chambers and Company, Limited, resigned from that appointment at the end of last year, having reached the retiring age. The Board of the Company have invited Mr. Gwyn to become a Director of two subsidiaries, the Thorncliffe Coal Distillation, Limited and N. C. Thorncliffe Collieries, Limited.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

A New Ingot Slicing Machine

ALMOST completely re-designed the "Craven" Ingot Slicing Machine is of somewhat simpler construction than its predecessor and embodies several important developments. Driven by a 100 h.p. variable-speed motor, the machine is specially designed for slicing steel ingots, up to 24 in. diameter and some 9 ft. maximum length, into "cheeses" of equal weight, suitable for subsequent hot working into railway wheel tyres. Up to nine parting cuts can be made simultaneously on this machine, using a $\frac{7}{8}$ in. wide square-section front parting tool and a $\frac{3}{4}$ in. vee-point rear parting tool for each cut. The tools are fed forward to about $2\frac{1}{4}$ in. diameter, leaving a vee-section finish at the bottom of the groove, and the parting is finally completed by hammer blows after the ingot has been removed from the machine. During tests on the machine, a 14 in. diameter ingot was parted into ten sections in 25 minutes, the maximum electrical current measured during the test indicating that only about 60 h.p. of the available 100 h.p. had been absorbed.

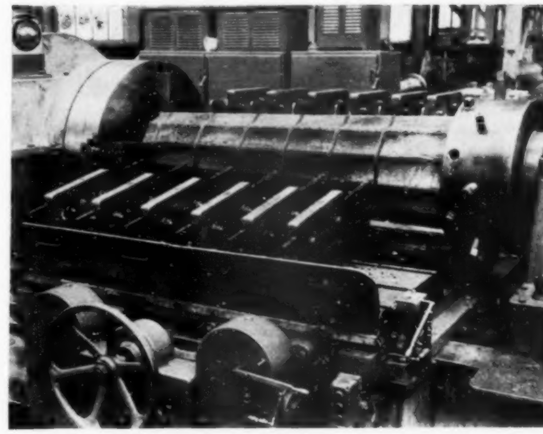
The headstock houses all the transmission mechanism from the motor input shaft to the high-carbon steel spindle, and includes primary spur reduction gears and both intermediate and final double-helical driving pinions and wheels. The steel faceplate has four independently-adjusted built-in jaws, and reversible jaw pads with offset location joggles enable the maximum range of ingot diameters to be gripped.

As cast, the ingots are slightly tapered, and it is normal practice for the thin end to be gripped in the headstock chuck, while the thicker end is supported by a heavy tailstock. A large, steel, bell-type chuck, secured to the front end of the tailstock spindle, is arranged with a series of set screws in such a manner that ingot ends ranging from $10\frac{3}{4}$ to 22 in. diameter can be effectively gripped without undue overhang of the screws.

The right hand end of the main bed has four slideways to receive the tailstock, but the central portion is increased in width, by the addition of two further shears, in order that the two directly-opposed saddles may be secured one to three front bed ways and the other to three rear ways. Each saddle carries a 4 ft. 10 in. upper tool slide, and removable extension wings secured to each end of the tool slide give an additional 11 in. width for the accommodation of a full quota of 18 toolholders. Both the wings and their supports can be removed when dealing with exceptionally short ingots.

The upper faces of the tool slides and their extensions are provided with tee-slots and joggles for securing the individual tool holders in position, the latter being spaced out to suit the required widths of slab. In this connection it may be mentioned that the taper in the ingot necessitates a careful calculation of each successive slab width in order that identical weights may be obtained. The parting tool blades are secured in their holders at the appropriate top rake angle, and extension supports obviate undue tool overhang.

Front and rear tool slides are traversed inwards simultaneously by means of four transverse feed screws



The Craven Ingot slicer in operation

coupled together through balanced worm reduction units and a cross shaft, hand operation being provided. Automatic power feeds, ranging from 40 to 80 cuts per inch, are derived from the headstock and applied through a four-change gear box and a front bed shaft. Rapid power traverse motion is also included, being driven from a separate $7\frac{1}{2}$ h.p. reversing motor situated on top of the feed gear box. Selection for feed or rapid traverse is effected by means of two lever-operated friction clutches inside the gear box.

An interesting feature of the machine is the automatic accelerating device, which comprises an electrical speed regulator operated from the transverse travel of the rear tool slide by means of a spring-loaded wire rope and chain mechanism. The regulator is set so that the work speed remains constant at its minimum of 6·5 r.p.m. for a given range of higher diameter cutting, after which the speed is progressively increased, as the cutting diameter decreases, until the maximum work speed of 19·5 r.p.m. is reached at a point approaching the smallest cutting diameter. By this means, a close approximation to a constant cutting speed is maintained throughout the operation.

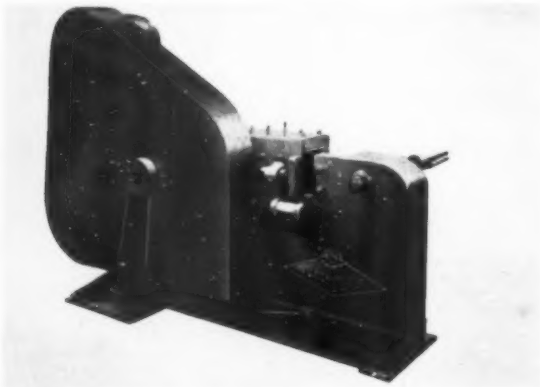
Craven Brothers (Manchester) Ltd., Vauxhall Works, Reddish, Stockport.

Bar Cropping Machine

THE latest addition to the Besco range of bar cropping machines is the BS.60F, which is considerably larger than the BS.32F and the BS.50F, requiring a $7\frac{1}{2}$ h.p. drive and being suitable only for floor mounting. This machine is capable of cutting up to 3×1 in. or $7 \times \frac{3}{8}$ in. flats; rounds of 2 in. diameter; and squares and hexagons up to $1\frac{3}{4}$ in. It will crop 7 bars of $\frac{3}{4}$ in. diameter, 16 of $\frac{1}{2}$ in. diameter, 28 of $\frac{3}{8}$ in. diameter, or 64 of $\frac{1}{4}$ in. diameter, in one operation, and with special blades, angles $3 \times 3 \times \frac{1}{2}$ in. can be cut with precision.

Powerfully built, the main frame is fabricated of welded steel plate, with an angle flange and plate for

bolting down. The strength of construction and shear pin device, fitted to protect the mechanism from overload, makes the machines virtually unbreakable. Vibration is kept at a minimum by the finely balanced flywheel, the main shaft of which runs in ball and roller bearings, and friction is combated in other parts of the machine by phosphor bronze bearings of generous dimensions and the adjustable bronze wearing linings in which the cropping ram moves. All are easily lubricated and capable of long service without renewal.



The BS 60F Bar Cropping Machine

The machine is driven by vee belts from a motor compactly mounted on an adjustable stand to allow of alteration of the tension of the belts. The clutch is of the multi-tooth dog type, accurately machined from a high tensile steel; it is manipulated by cam action for releasing and by coil compression springs for engaging when the foot treadle at the base of the machine is depressed.

Gauges are fitted for setting bars and rods for cutting to a given length. These are positioned so as to clear falling lengths after shearing, and a roller is fitted to the cropping gap to facilitate the forward movement of heavy bars or bundles of rods up to the gauge face.

F. J. Edwards Ltd., 359–361, Euston Road, London, N.W.1.

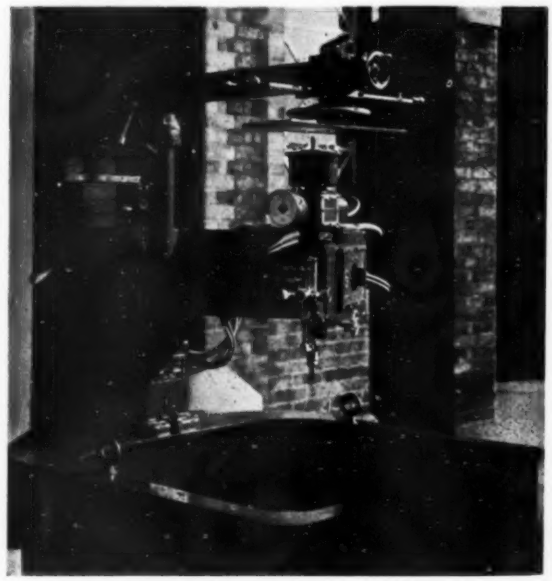
Improved Flame-Cutting Machine

An improved version of their 36-in. Universal Cutting Machine is announced by The British Oxygen Co. Ltd. The general appearance of the machine is much the same as that of the original, since basic movement and capacity, e.g., a 36-in. cutting radius and a 6-in. maximum cutting thickness for mild steel, remain unaltered. There are, however, a number of modifications covering the cutter and its controls, the oxygen control panel, the speed control for the template follower, and a new drive for the last named, together with other small refinements.

An innovation that will be welcomed by machine operators, is the introduction of the M.C.6 cutter which uses the B.O.C. one-piece nozzle. The adoption of the one-piece nozzle on this machine, with the advantage of trouble-free operation and the ease with which nozzles can be changed, is a most important feature. A further advance is that a powder cutting attachment can be fitted for profile cutting. This will be available shortly and should prove of great interest to industry for it will greatly extend the scope of the machine. The cutter is finished in chrome and all corners have been rounded so as to make cleaning a much simpler task. In addition, the gas controls on the cutter now have colour identification and are much larger.

The speed control has been changed and a rotary rheostat replaces the old-type sliding model. The "on–off" and the "forward and reverse" switches have also been altered and together with the rheostat they have been mounted on a neat panel on the outer arm. Modifications have been made, too, to the gate arms, the cast girderwork being replaced by a neat panelling which tends to lighten the arm and at the same time results in a cleaner appearance.

Another innovation is the oxygen control panel mounted on the left-hand side of the pillar and protected from damage by a chromed steel strip. The panel consists of the latest type O.R. 13 regulator which has been split up to enable grouping of the gauges at the top of the panel. A cutting chart is also included. The acetylene supply is still controlled by an A.R. 9 regulator fitted to either a cylinder or a manifold. Below the control panel is a master "knock-off" valve which governs both the oxygen and the acetylene supply to



The improved 36in. Universal Cutting Machine

the cutter, enabling all gases to be cut off with one movement.

The re-designed transmission to the tracer head incorporates an oil-bath in which the oil level is visible through a glass panel. A further worthwhile refinement is the provision of a hinged bracket on the pillar which can be fitted over the magnet roller and so prevents movement of the arm when the machine is not in use, or when the work is being set up.

The British Oxygen Co. Ltd., Bridgewater House, Cleveland Row, St. James', London, S.W.1.

CURRENT LITERATURE

Book Notices

Principles and Methods of Sheet-Metal Fabricating

By George Sachs, 9 × 6 in. 526 pages, published by Reinhold Publishing Corporation, New York, and by Messrs. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 80s.

THE various processes developed for the cold-working of metals have been operating for many decades; in recent years, however, a fuller knowledge has been obtained of their effect on the material processes and, in consequence, great progress has been effected, not only in plant and equipment employed and in their manipulation, but in technique, with the result that quality of products and speed of production have greatly improved. Most cold wrought ferrous and non-ferrous metals are in the first instance produced by rolling, drawing, or extrusion, and it is sheet metal with which the author is primarily concerned in this book.

In the production of ferrous and non-ferrous sheet there has been much fruitful investigation of rolling and recrystallisation textures, some of which has led to important practical results. In the manufacture of cartridge brass, for instance, it is now known that the finished material should be free from preferred orientation or other directional effects. Apart from metallurgical aspects, however, there have been extensive studies of a variety of operations in sheet-metal fabricating which have resulted in a large number of design and forming rules being developed, and this book describes in great detail the principles of numerous forming methods employed and the production equipment involved.

The subject matter is admirably covered in five main parts. Part I, as an introductory section, deals with sheet metal and sheet-metal parts, covering part design and metal properties, formability tests, the development of sheet materials, their general properties, and the design, layout, and preparation of blanks. Part 2 is concerned with the principles of forming various part types and discusses bending and straight flanging, forming of parts with contoured flanges, contour forming of sections, forming of deep recessed parts and of shallow recessed parts. The principles of deep drawing are given in Part 3, which describes the drawing of thin-walled cylindrical cups, re-drawing or sinking of tubular parts, ironing of tubular parts, drawing of thick walled cylindrical cups and of box shaped parts. Press-die forming is discussed in Part 4 covering equipment, tools and lubrication for press-die forming of sheet metal parts, press-die forming from developed blanks, press-die forming of recessed parts, cartridge case fabricating and impact extrusion and coining. The last section, Part 5, is concerned with forming methods, and includes drop hammer forming rubber forming, stretch forming of smoothly contoured sheet metal parts, contour forming and roll bending, roll and draw bench forming straight sections, and spinning and roller flanging.

From this brief summary of the contents of this excellent book it will be appreciated that the author has taken great pains to deal comprehensively with the subject, and in doing so he has presented knowledge which should help all in the metal-working industry to reduce materially the expensive waste in time and material which is frequent in sheet-metal fabricating. The book is well illustrated and admirably produced and, despite the high cost, will be regarded as invaluable to the progressive sheet-metal fabricator. B.S.

The Corrosion of Steel in Steel Houses

National Building Studies Special Report No. 16. Published by H.M. Stationery Office for the Department of Scientific and Industrial Research. Price 1s. 9d. (45 cents U.S.A.), by post 1s. 10½d.

THIS publication presents the results of a limited survey of steel framed houses built between 1920 and 1927. The survey was undertaken to obtain information on the efficiency of the protective coatings applied to the houses when they were erected.

Some sixty houses of eight different types of construction were examined in various parts of the country. The steelwork in many of the houses had received no maintenance (apart from the painting of exposed surfaces) since their erection. The investigation covered the study of details of design likely to permit the penetration of moisture, the effectiveness of protective coverings, the effect of mechanical damage, the extent of atmospheric pollution and other possible causes of corrosion. In one case a rockery built to a height of eighteen inches against the steel cladding of the house caused serious corrosion.

The report concludes that two coats of paint will provide adequate protection in wall cavities unless faults of design permit rain to penetrate into the cavities. Little condensation was found in cavities but in buildings with internal linings of high thermal resistance special care should be taken in protecting steelwork. Faults in design leading to corrosion included :—steel stanchions erected in contact with wet clinker concrete without previous protection of the metal and the omission of watertight jointing between sheets of cladding. The report emphasises the importance of watertight window frames, regular painting and the avoidance of water traps at the base of the cladding. In the absence of attention to these points serious corrosion is likely to take place.

The Working of Aluminium in the Shipyard

Information Bulletin No. 18 of a series published by The Aluminium Development Association, 33, Grosvenor Street, London, W.1. Price 2s.

THIS booklet consists of practical information which is not only suitable for instructing operatives but will be found helpful to drawing office staff. The bulk of the publication is divided into four sections, viz., the working of platers material; sheet metal work; machining; methods of joining. The last section includes very recent information concerning the development of larger aluminium rivets and driving practice and also information on argon arc welding in addition to the older methods. Recommendations are given on treatment, where necessary, of aluminium in contact

with other metals, with timber and concrete, etc. There are also sections on painting, anti-fouling compositions and deck compositions. There is a brief reference to methods of storing heavy sections and thin material and on the identification of aluminium alloys. Three Appendices deal respectively with : (1) aluminium alloys recommended for marine work ; (2) British Standards and the available forms and sizes in which aluminium is supplied ; (3) a note on the heat treatment applied to appropriate materials in order to improve their strength and other properties.

Trade Publications

"SERVICE TO INDUSTRY," the slogan of Hadfields Ltd., is also the title of a new illustrated brochure issued by the Company. In an introductory historical section, the progress of the Company is traced from its foundation in 1872, by Robert Hadfield, father of Sir Robert Hadfield, Bt., F.R.S., to the present day. Reference is made to the influence of the Hadfields, father and son, on the development of the firm and on the civic progress of Sheffield. The activities of the Company were in the early days confined exclusively to the production of steel castings, then a new field of manufacture. Gradually, the scope of their activities was extended and to steel castings were added the production of high quality steel in billet and bar form, and a wide range of forgings and heavy engineering products. The brochure presents a brief illustrated account of the facilities available, including melting shops, foundries, rolling mills, forges and machine shops, reference also being made to the work of the research department in the development and testing of both new and established materials and products. In an outline of the manufactures of the Company, particular attention is paid to "Era" Manganese Steel, Trackwork, Colliery and Mining Equipment, Crushing Machinery, Heat Resisting Steels, and Non-Corroding Steels.

WE have received an interesting technical brochure from Tyseley MetalWorks, Tyseley, Birmingham. Excellently produced and illustrated, this 70-page book deals with the general activities of the company as manufacturers of ingot metals. It has been compiled primarily for the foundry interest, and does not, therefore, include the alloys manufactured at Tyseley for the stamping, extruding, rolling and allied industries, which are all catered for with a complete range of alloys in suitable form for individual requirements. In an interesting foreword, the managing director, Mr. G. W. Booth, outlines the growth of the ingot trade from the days when "rule of thumb" methods prevailed to the present scientifically controlled industry.

A COMPOSITE reprint from the English Electric Journal has recently been issued by the Company, dealing with English Electric equipment for the hot strip mill at Messrs. John Summers & Sons, Ltd., Shotton. A description is given of the main electrical plant associated with this hot strip mill which produces some 470,000 tons of strip a year, while further articles concern the modernised flying shear which has been fitted with electronic control gear to increase the sensitivity of speed matching, and thus to enable lengths of plate to be cut more accurately.

THE latest publication of General Refractories, Ltd., Genefax House, Sheffield, 10, is a folder containing a series of leaflets giving particulars of the range of basic refractory bricks made by the Company. These include fired bricks in chrome, magnesite, chrome-magnesite, magnesite-chrome and dolomite, and chemically bonded bricks in chromite, chrome-magnesite and magnesite-chrome. Details are given of chemical and physical characteristics and examples of typical applications listed.

WE have received from John Wilkins & Co., Ltd., 231–243, St. John Street, Clerkenwell, E.C.1, a novel perpetual calendar decorated with panels displaying 44 of the Company's metal finishes. These include 12 examples of anodised finishes ; protective plating with tin, copper, cadmium, nickel, zinc, brass and chromium ; 7 samples of metal colouring ranging from antique gold to oxidised copper ; decorative plating in matt gold, satin chromium, gold, bright nickel, brass, silver, copper and rhodium ; and 8 enamelled finishes—mock gold, polychromatic, acid resisting, infra-red stoving, hammer finish, cellulose, wrinkle and air-drying.

LEAFLETS have now been issued by Sunvic Controls, Ltd., dealing with two new instruments which were referred to in the 'Recent Developments' section of our December 1951 issue. They are the Type RT.2 Resistance Thermometer Proportional Controller for use with creep test furnaces, muffle furnaces, electric ovens, etc., and a Thermostatic Relay, Type ED.2 for use with water baths, incubators, sterilizers and the like. The leaflets are numbered RT.13A and ED.10A, respectively.

Books Received

"ELEMENTS of Physical Metallurgy," by Albert G. Guy. 293 pp. inc. appendix and index. Cambridge, Mass., 1951. Addison-Wesley Press, Inc. $6·50.

"Metallurgische Verarbeitung von Altmetallen und Rückständen" Band II : "Altrometalle," by Edmund R. Thews. 290 pp. inc. index. München, 1951. Carl Hanser Verlag. 3050 D.M.

"Percival Norton Johnson." The Biography of a Pioneer Metallurgist. By Donald McDonald. 224 pp. inc. appendices and index. London, 1951. Johnson Matthey & Co., Ltd. 30s.

"The Science of Flames and Furnaces," by M. W. Thring, M.A., F.Inst.P., F.Inst.F. 416 pp. inc. index. London, 1952. Chapman & Hall, Ltd. 42s. net.

"Gli Acciai Communi E Speciali," by Gastone Guzzoni. 5th Edition. 829 pp. inc. appendix and indices. Milan, 1952. Ulrico Hoepli. Lire 5800.

"Welding Practice." Vol. 1, "Welding Methods and Tests." Edited by E. Fuchs, M.A., A.M.I.Mech.E., and H. Bradley, M. Met. 130 pp. inc. index. London, 1951. Butterworths, Scientific Publications in association with Imperial Chemical Industries, Ltd. 55s. net for 3 Vols. 17s. 6d. for Vol. 1 ; by post 1s. extra.

"Testing of Measuring Equipment." Ralph W. Smith. National Bureau of Standards Handbook 45. 205 pp. Washington, 1951. United States Government Printing Office. $1·25.

METALLURGICAL DIGEST

Direct-Chill Casting of Aluminium Alloys

By W. E. King

WHEN developments after the first world war required the production of large ingots in the complex heat-treatable aluminium alloys, it was found that the cold-mould process, which at that time was being used for ingots of small size and of simpler composition, was far from satisfactory. Ingots tended to crack severely during hot rolling or forging, contained a large amount of porosity, and showed considerable segregation of the alloying constituents. Studies of casting conditions and of ingot structures indicated that the main drawback to the process was the slow rate of heat removal, which became more important as ingot size increased.

Several casting methods were introduced to produce more satisfactory ingots, but the slow rate of heat extraction seemed to be the main objection to their general use. This was caused by the insulating effect of the air gap between ingot and mould that resulted from the original solidification and contraction of the ingot surface. Some means had to be developed to eliminate this obstruction to heat flow. A solution for this problem was found by removing the mould, after a shell sufficiently strong to support the molten metal had frozen, and then spraying water directly on the ingot surface. It was considered that the best way to do this was by a downward movement of the ingot in the mould. Such a procedure became possible if the mould was smooth and sufficiently cooled so that shrinkage took place immediately on contact with the mould, and thus gave the necessary clearance for slippage. It was found that the metal depth in the mould during casting should be shallow so that the ingot surface could be cooled directly, and thereby provide a narrow freezing zone and rapid heat extraction from the ingot centre.

The direct-chill process, as developed at Massena in 1934, is shown diagrammatically in Fig. 1. This shows a thin mould made of a high-conductivity metal that is open both at the top and the bottom. While the bottom of the mould is closed temporarily by means of a metal bottom-block, molten metal is introduced into the mould through a pouring spout. The bottom-block and solidifying ingot are withdrawn from the mould at a constant rate, and the introduction of molten metal controlled so as to maintain a constant depth of metal in the mould. The outer shell of the ingot is frozen by transfer of heat through the mould to cooling water, and the entire central portion by direct flow of heat through this shell and to an envelope of water that flows down the exposed surfaces of the ingot as it emerges from the mould.

It was soon evident that a very high rate of cooling had been achieved in all parts of the ingot by this process, including the all-important central portion, and the entire ingot showed a very fine uniformly distributed constituent structure. The ingot was sound and had a fine equiaxed grain structure, and segregation was less than had been found in any other type of ingot. The hot-working characteristics were excellent, with the centre sufficiently strong to resist the internal forces that had caused rupturing in other types of ingots during hot-rolling.

By the end of 1935 this direct-chill process had been used in the casting of many ingot sizes and shapes. These included round extrusion ingots, large rectangular ingots for sheet and plate rolling, and hollow round ingots for the extrusion of tube blooms. Casting of the latter ingots involved the use of a tapered water-jacketed core supported in the centre of the mould.

The great disadvantage of the process is internal cracking caused by the internal stresses that result from the rapid cooling. Under such conditions, the cracking extends to the surface during casting, and ingots have even fallen into two or more pieces shortly after being removed from the casting unit. By careful control of the important factors involved, it is possible to-day to keep the loss from this defect to 1% or 2% or less. A second disadvantage is the liquation commonly found on the surface of these ingots. Since this liquation layer is relatively brittle it is necessary to scalp the surface of ingots either before or after the initial hot-working operation.

This direct-chill process has been used for a great number of types and sizes of ingots. The author's company (The Aluminium Company of America) had more than 60 units in operation in the war year 1944. Molten metal is led to the casting units directly from large stationary melting or holding furnaces, or is transferred from furnaces to casting units in electrically heated ladles of about 5,000 lb. capacity.

The mould is generally made of rolled aluminium sheet, although bronze and copper have been used successfully. It is usually ¼ in. thick and from 3 to 10 in. in height, depending on the type and shape of ingot being made, and is cooled by either a water spray or a water jacket. The

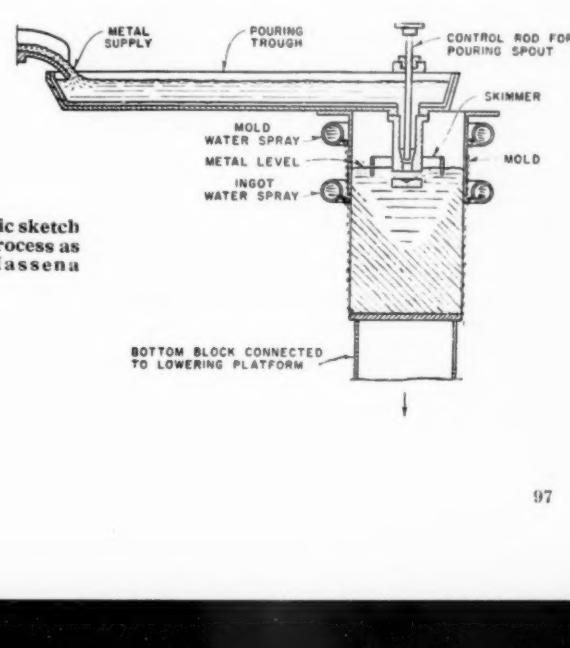


Fig. 1. Diagrammatic sketch of the direct-chill process as developed by Massena in 1934.

From *Mechanical Engineering*, **73** (Nov. 1951,) 877–81.

ingot is generally cooled by a separate spray impinging on the ingot surface directly below the lower edge of the mould. A heavy oil is used as mould lubricant.

The height of metal maintained in the mould during casting is generally from about 2 to 7 in., depending on the alloy, size and type of ingot being cast. The ingots are lowered at rates from about 1½ to 7 in., or more per minute, depending again on alloy, size and type of ingot. Sheet-ingot sizes are from 8 × 30 in. to 12 × 48 in., extrusion ingots from 6 to 18 in. diameter and forging and rolling ingots from 6 to 24 in. square. Ingot lengths run up to about 12 ft. Sheet-ingot weights range from 1,200 to 7,800 lb., extrusion ingots from 300 to 2,700 lb., and forging and rolling ingots from 700 to 6,000 lb.

Single Draw Produces Silicon-Copper Hemispheres

By James A. Leake

HEMISPHERES of silicon-copper alloy are among products produced by the Leake Stamping Co., Monroe, Mich., in a single draw. The set-up includes a Clearing double-acting hydraulic press equipped with three dies. Only one of these is employed for drawing, which, in the deepest size, is 13 15/16 in. deep and has a 10½ in. spherical radius. The full depth is drawn in a single stroke, the draw die being between the other two in the set-up. During the same stroke, a die at the left restrikes the piece to produce a sharper radius at the flange. At the same time, a die at the right pierces holes and also trims the flange to size.

Thus, although three pieces are in process in each working stroke, one piece is finished at each such stroke. Actually, a single set of dies having some interchangeable inserts produces hemispheres of four different types and having different depths, hole sizes, and location. All the hemispheres are of the same diameter. One size is 10½ in. deep. The others also have hemispherical bottoms but include cylindrical portions between the flange and the hemisphere itself, this accounting for the different depths of draw.

Before this set-up was developed, others found it necessary to make three separate draws with annealing between to produce these parts. This, of course, slowed the job and made it much more expensive, besides necessitating much extra handling and tying up extra equipment. With the present set-up, there is no annealing between operations. It is necessary, as before, to stress relieve the stampings after they come from the press to avoid possible stress cracking at a later date.

Nominal composition of the alloy employed is a 3% silicon, 1% manganese, and the remainder copper. This alloy has excellent physical properties approximating those of mild steel, and has high resistance to corrosion. These properties make the alloy well adapted for use in tanks and pressure vessels. Stock used in making the stampings is 0·064 in. thick and is purchased in the annealed condition in square blanks ranging from 31 to 34 in., depending upon the depth of draw required.

After press operations are completed, the hemispheres are transferred to a Despatch oven of 64 cu. ft. capacity and are heated for one hour at 780° F. to effect the stress relief. Heating of this oven is controlled by a Leeds and Northrup potentiometer from thermocouples attached directly to the work. By this means, the temperature is held within a ± 4° F. temperature range. Finished parts are checked for hardness and stress relief and samples are tested for tensile strength. These hemispheres are excellent examples of deep drawing and have been produced in large volume with excellent records in service.

From *The Iron Age*, (22), **168** pp. 84–85.

New Chromium Carbides Resist Heat and Corrosion

CHROMIUM carbide is now being produced in limited quantities by the Carboloy Department of General Electric Company in a series of compositions. Corrosion tests made on these carbides by the manufacturer, and at Battelle Memorial Institute, indicate excellent resistance to corrosion by a number of agents. In the salt-spray test, samples were held in a 30% salt mist for 750 hrs. At the end of that time the samples retained their metallic lustre and showed no other evidence of corrosion. Tests made with strong mineral acids, including sulphuric and nitric acids, gave the chromium carbide about 30 times the resistance of 18:8 stainless steel and about three times the resistance of the standard carbide materials when sulphuric acid was used, and about twice that of the stainless steels and eight times that of other carbides when nitric acid was the corrosive agent.

The new carbides are reported to be practically inert under all test conditions involving the weak organic acids, including citric and lactic acids. As these acids are among the most common in food fermentation, the materials should have possibilities in the food processing equipment field.

Resistance to oxidation at high temperatures is so good that such uses promise to be among the most important for the new carbides. Chromium carbide seems to be almost completely resistant to oxidation at all temperatures up to about 1,100° C. Samples exposed to a temperature of 1,000° C. for 24 hrs. retained their lustre, while tungsten carbide samples in the same test completely disintegrated.

An important feature of the new series of chromium carbides is that the materials are less critical in supply than tungsten or cobalt, the bases for most of the cemented carbides.

Chromium carbides are made with a carbide powder of about 70% chromium, and nickel is used as the matrix material.

The new carbides appear to be stable when formed, and internal stresses have not appeared in pieces made with them. Forming methods are the same as for other carbides, and there seems to be no physical limitation upon the size and shape of the piece when the proper equipment is available. The workpiece has sufficient toughness to withstand grinding without chipping at the edges, and brazing and mechanical attachment can be accomplished in the tipping of tools in the same manner as with the other carbides. It can also be fastened by means of adhesives of the thermo setting plastics types where such bonding is indicated.

From *Materials and Methods*, **34**, (Dec., 1951), 69.

LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

FEBRUARY, 1952 Vol. XLV, No. 268

The X-Ray Diffraction Study of Single Crystals of Lead

By Y. C. Chuang, M.Eng., Ph.D.
Department of Metallurgy, Liverpool University

Whilst engaged upon the study of ageing phenomena in alloys of lead and tin, the author devised a method for producing cylindrical single crystals of lead, suitable for X-ray diffraction work. The orientation of these crystals was determined by a back-reflexion Laue method, and rotation photographs of such crystals having the (110) *axis as the rotational axis, have been indexed.*

MANY accounts of the methods by which metal single crystals can be produced have been published in the technical literature ; a summary is given by C. F. Elam[1]. In brief, large metal crystals may be made :—

(1) directly from the molten metal ;
(2) from the solid metal by a suitable straining and annealing treatment ;
(3) by deposition from the vapour phase.

Though large crystals are always present in ingots and slowly cooled castings of lead, the preparation of specimens suitable for examination by the X-ray single crystal technique is difficult. The metal is so soft that it is impossible to machine a cylindrical specimen less than 1 mm. in diameter from a large grained ingot without distorting the crystal. This difficulty has been overcome by growing a crystal of the exact size required directly from the molten metal. To do this one end of a ¼ in. Pyrex tube is drawn into a fine capillary, having a bore less than 1 mm. in diameter, and sealed at the end (Fig. 1). Lead is introduced into the open end of the tube which is then connected to a vacuum pumping system. On applying heat to the metal it melts and falls by gravity into the capillary. When full the capillary is sealed off under vacuum and placed inside a small electric tube furnace, the temperature of which is maintained at 40° C. above the melting point of lead. The metal in the capillary is thus remelted, and then allowed to cool slowly. In this way a single crystal less than 1 mm. in diameter is produced.

Difficulty was encountered in removing the specimen from the tube as it was impossible to break the glass without distorting the crystal. This distortion, though not revealed by ordinary chemical etching, is clearly shown by the pronounced asterism observed in the back-reflexion X-ray photograph. A chemical method for dissolving the glass was evolved, advantage being taken of the fact that lead is not attacked by hydrofluoric acid. The capillary tube containing the specimen is placed in a platinum crucible to which hydrofluoric acid is added, and after heating to a temperature of 50°–100° C. for fifteen minutes the glass is dissolved and the specimen is ready for mounting in the X-ray camera. Specimens prepared in this way do not show any asterism.

[1] C. F. Elam. "Distortion in Metal Crystals", Clarendon Press, Oxford, 1935, pp. 2–6.

Determination of Crystal Orientation

The orientation of the crystal may be determined by the back-reflexion Laue method, the specimen being mounted on the goniometer head of a rotating single crystal camera. Tungsten white radiation is used and the back-reflexion Laue pattern recorded on a flat plate.

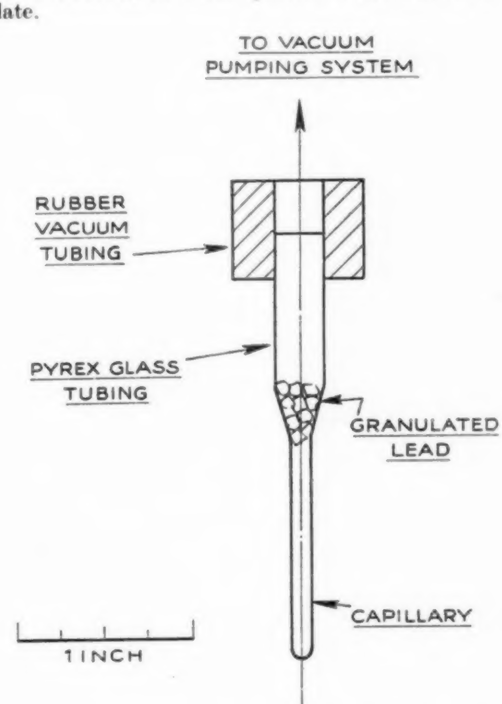
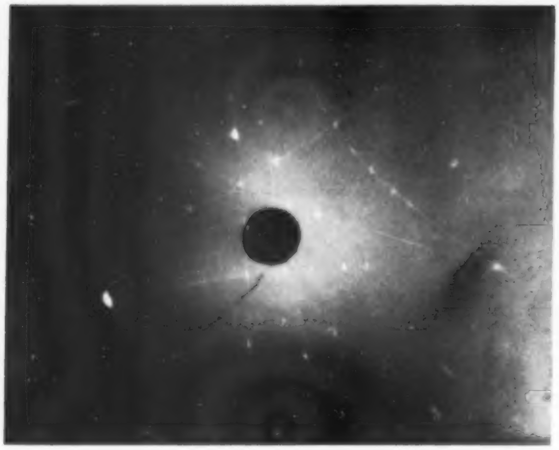
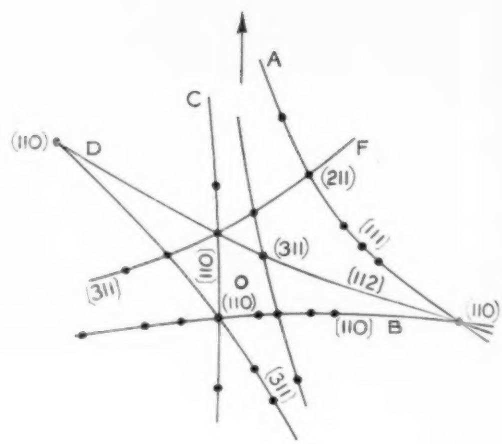


Fig. 1.—Arrangement for feeding molten lead into the capillary.





2.—Back-reflexion Laue photograph of a lead single crystal. Exposure conditions : tungsten white radiation, at 40kV, 15 mA for 1 hour. Fig. 3.—Identified pattern of Fig. 2.

Fig. 2 shows the back-reflexion Laue photograph of a crystal of lead mounted vertically. It will be seen that the Laue spots lie on hyperbolæ. All spots lying in the same hyperbola are reflexions from planes parallel to a common direction known as the zone axis. In the pattern obtained from a cubic crystal structure there are prominent rows of spots from the zones (100), (110), (111) and less prominent ones from (113). Spots at the intersection of the principal hyperbolæ are reflexions from planes common to the principal zones[2]. In the face-centred cubic system these are (100), (110), (112) and (111). Bearing these facts in mind—and with the help of a Greninger chart for reading angular relations, a stereographic net, and a table giving the angles between prominent zones—most of the hyperbolæ and spots can be identified ; details of these procedures have been fully described elswhere[2]. The indices of the zone axes and principal planes of the crystal under examination are shown in Fig. 3.

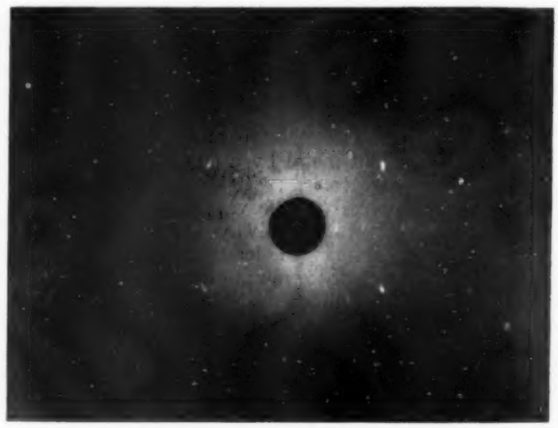


Fig. 4.—Back-reflexion Laue photograph of a lead single crystal, (110) vertical, showing two-fold symmetry.

The majority of crystals grown by the above method were oriented with the (110) axis nearly parallel to the length of the specimen and thus this was the most convenient axis to set coincident with the axis of rotation of the goniometer head. A back-reflexion Laue photograph of a crystal with the two-fold axis (110) vertical is shown in Fig. 4. Without disturbing the setting of the crystal rotation photographs were obtained using unfiltered cobalt and copper radiations. The patterns, recorded on concentric cylindrical films, are shown in Figs. 5 and 6. The reflexions are arranged in layer lines, the spots on the central layer line being reflexions from planes whose zone axis is the axis of rotation, i.e. (110).

The photograph of a single crystal rotated about a principal axis is usually indexed by the Bernal method. To apply this method to the crystals rotated about the (110) axis it is necessary to choose an unusual unit cell

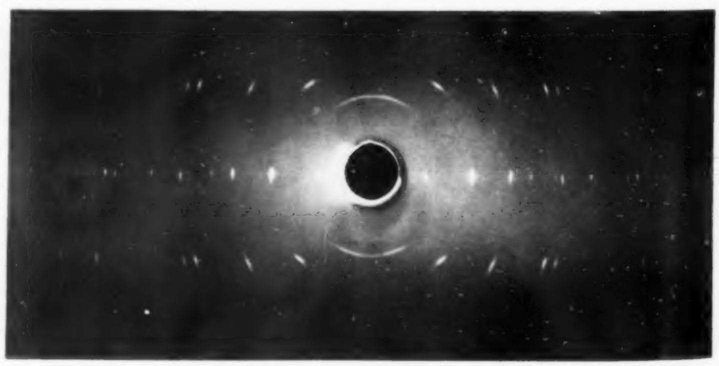


Fig. 5.—Rotation photograph of a cubic crystal of lead about the (110) axis, taken on a cylindrical film in a 59 mm. diameter camera. Exposure conditions : unfiltered cobalt radiation at 45 kV, 20 mA for 1½ hours.

2 C. S. Barrett, "Structure of Metals," McGraw Hill, New York, 1943 pp. 167–172.

with a major axis parallel to the axis of rotation. However, the photograph may be indexed more easily in the following manner.

The spots on each layer line must satisfy the following condition[3] :—

$$hu + kv + lw = n \ldots\ldots\ldots\ldots(1)$$

where : (h, k, l) are the indices of each spot ; (u, v, w) are the indices of the axis of rotation ; n is the number of the layer line to which the spot (h, k, l) belongs, the central line being taken as zero.

Since the axis of rotation is (110), equation (1) is reduced to :—

$$h + k = n \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

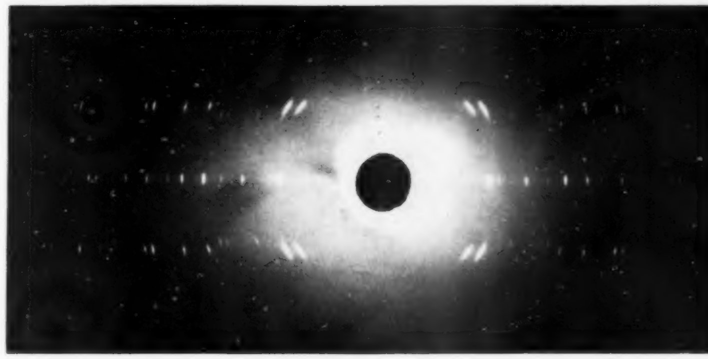


Fig. 6.—Rotation photograph of a cubic crystal of lead about the (110) axis. Radiation-filtered copper.

Calculation of the theoretical relative intensities of reflexions from a lead crystal shows that reflexions will be absent when h and k are mixed odd and even, i.e. when n is odd. Hence for the present setting odd layer lines will be missing. The values of n thus can be determined by inspection. The values of θ for each spot were measured by superimposing a θ-ω chart on the pattern. General indices were then assigned to each of the Debye-Scherrer rings and individual spots were indexed by considering the limitations imposed by the condition expressed in equation (2). The results are shown in Fig. 7.

[3] C. S. Barrett. *Ibid.*, p. 101.

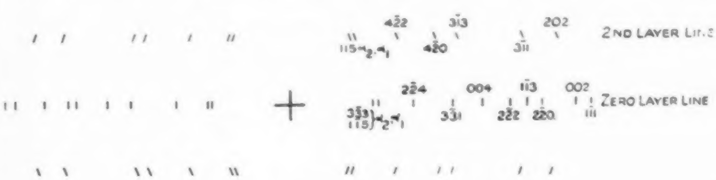


Fig. 7.—Identified pattern of Fig. 5.

Acknowledgment

This work was carried out in the laboratory of the Department of Metallurgy, University of Liverpool, under the supervision of Dr. S. J. Kennett to whom the author is indebted. Grateful thanks are also due to Dr. W. S. Owen for his advice and encouragement.

Transparent Silica Centrifuge Tubes for Micro and Semi-Micro Work

By W. Stross, M.D., F.R.I.C.

THE advantages of the centrifuge for semi-micro and micro work need hardly be emphasized. Many workers must have felt that it would be advantageous if precipitates collected by centrifuging could be dried, ignited, weighed and fused with fluxes in the centrifuge tube in which they were precipitated and collected. This applies particularly if it becomes apparent only in the course of the analytical work, that ignition and fusion are necessary.

Quite a long time ago L. Pincussen[1] suggested porcelain centrifuge tubes for the gravimetric determination of sulphate as the barium salt. The fact that these tubes are not transparent is an obvious disadvantage.

Recently G. Beck[2] recommended a centrifuge tube, the bottom of which is detachable and serves as crucible ; it is connected to the top part by a ground joint, and is made from glass or porcelain. The device is called "Zentrifugiertiegel."

For a considerable time now the writer has been using centrifuge tubes (with rounded bottom) made from transparent silica, 60 × 9 mm. (I.D. 7½ mm.) for micro, 80 × 16 mm. (I.D. 13 mm.) for semi-micro work. The larger tubes are sufficiently wide to enable the contents to be boiled over a flame without greater risk of bumping than in ordinary macro test tubes. They are sufficiently light (larger size about 12, smaller size 2·5 grams) to be weighed on a micro or semi-micro balance.

For the larger tubes, buckets, slightly larger than the original ones, were fitted to the usual micro hand centrifuge. These were made by drilling and turning aluminium rod.

Precipitates can easily be dried, weighed and ignited to high temperatures (well over 1,000° C.)[3], and fused without transfer. The drying is particularly quick if the precipitate can be given a final wash with alcohol or acetone, etc.

Insoluble precipitates can easily be fused in these tubes with potassium bisulphate. Alkaline fusion is, of course, not possible.

These experiments were carried out in the laboratories of International Alloys, Ltd., Aylesbury, Bucks. The author wishes to thank the Directors of the Company for permission to publish this note.

[1] L. Pincussen, Mikromethodik, G. Thieme-Leipzig, 1930, p. 12.
[2] *Analytica Chim. Acta* 4, (1950), 245.
[3] For the necessity of using high temperatures for e.g., the ignition of aluminium hydroxide, see E. C. Mills and S. E. Hermon, *Metal Industry*, **76**, (1950), 343.

The Identification of Metals and Alloys By Chemical Spot Testing

By C. T. Wilshaw, A.I.M.

The spot testing procedures described in this article have been developed for the identification of materials rather than the detection of the presence of a particular element. The scheme covers ferrous materials and those non-ferrous alloys not readily separated from them by their density or colour.

MOST spot testing procedures which have been described are concerned with identifying specific alloying elements present in a material but, as many heat and corrosion resisting alloys contain the same alloying elements, that technique is not very useful in distinguishing between them. It is, therefore, desirable to have a method of identifying an alloy directly, rather than by determining the alloying elements present. The procedure which will here be described has been devised with this object in view and will, perhaps, be particularly useful in plants such as oil refineries, chemical works and aero-engine factories where large numbers of alloys are employed.

Many readers will be familiar with the precautions to be observed in conducting chemical spot tests, but it is worth reiterating the more important points. First amongst these is the necessity for correct surface preparation, as tests must be made on *bright freshly-prepared* surfaces. Even in the case of bright corrosion-resistant materials, it is essential to remove invisible surface films before proceeding to apply the solutions. Surfaces are best prepared by the use of a smooth file and/or emery cloth, but if the condition necessitates grinding, light pressures should be used and the preparation completed by file and emery, dust being removed with a piece of filter paper. The final surface should be that given by Grade F emery. A horizontal surface or edge should be chosen for testing; with the type of test to be described, a quite erroneous result will be obtained if the drop of solution is not stationary on the surface to be tested. The solutions which are employed should be standardised regularly against known materials and protected from contamination. 30 ml. dropping bottles fitted with ground-in pipettes will be found convenient for keeping and applying the solutions. Finally, it should be realised that tests must be made in the order shown in the table; random testing may give misleading results. In certain cases, where the range of possible materials is limited, one or more stages in the procedure can be omitted, e.g. if the alloy is known to be a stainless steel of some type, solutions 1 and 2 need not be used. Usually, however, it is better to go through the procedure completely.

It is clearly impracticable to advance a scheme which would cover all metals and alloys, and this procedure deals only with ferrous alloys and those non-ferrous alloys not readily separated from them by their density or colour. Even so, the range of materials which it is possible to encounter is very considerable, and only a representative selection can be described. It is thought, however, that this selection will include a good proportion of the alloys used in those plants which would be the most interested in operating a procedure of this type. Moreover, as will be indicated later, some of the tests are capable of modification to adapt them for the differentiation of the user's range of alloys. It cannot be too strongly emphasised that a prospective user of the procedure, having made up his solutions, should standardise the solutions against samples of known materials and familiarise himself with the reactions. Experience will then dictate what modifications are necessary to deal with materials not mentioned below.

The Solutions

Solution 1

Concentrated Nitric Acid	1 part
Distilled Water	1 part

When cool, standardise against known materials and adjust the concentration, if necessary, to give the reactions shown in the table. Raising the acid content increases the speed of reaction with the group of non-ferrous alloys quoted and lowers the chrome content at which passivity is registered with the chrome steels. Reducing the acid content has, of course, the reverse effect. Unless special effects are desired, little adjustment to the solution should be necessary.

To use the test, apply one drop of the solution to a prepared spot on the unknown material and observe the reaction, if any, for one minute. The user should familiarise himself with the reactions which occur on the materials to be encountered. They are characteristic in each case, and experience of them will obviate the possibility of errors arising from misinterpretation of written descriptions. With certain alloys, a reaction lasting for only a fraction of a second may be noted immediately after applying the test solution. Such a result is classed as " no reaction or stain " in the table together with the cases where this is more literally true. Again, actual experience of this (with, for example, 5% chrome steel) will make classification simple.

Solution 2

Copper Sulphate ($CuSO_4.5H_2O$) ..	24 g.
Distilled Water	100 ml.

Standardise against a sample of 5% chrome steel; copper should deposit on the steel after about 10 secs. To achieve this, the solution may need the addition of a few drops of dilute sulphuric acid. If too much acid is added, copper will deposit on higher chrome steels also; to guard against this, check the solution against a sample of 7% chrome steel.

To use the test, apply one drop of the solution to a freshly prepared spot on the steel and observe for one minute.

Solution 3.

Copper Chloride ($Cu\ Cl_2$)	10 g.
Concentrated Hydrochloric Acid ..	13 ml.
Distilled Water	50 ml.

To use the test, apply one drop of the solution to a freshly prepared surface and observe for one minute. The solution on the specimen may or may not discolour, but it is a layer of copper on the metal surface which is of importance. To facilitate observation, the solution may be gently blown aside after one minute. Only a continuous layer of copper is significant; any etching of the specimen is to be ignored.

Solution 4

Concentrated Nitric Acid	1 part
Phosphoric Acid (H_3PO_4–85%) ..	1 part
Distilled Water	2½ parts

To use the test, apply one drop of the solution to a fresh surface and observe for two minutes. As will be seen from the table, this solution is used for distinguishing between the 7%, 9% and higher chrome steels. The response of the steel changes rather sharply at about 9% chrome. Consequently, within the range 8½% to 9½% chrome the response may vary from an appreciable reaction to a mere staining of the bright steel surface. 11% and higher chrome steels, however, are not even stained by the solution within the two minutes prescribed. The 9% chrome steel usually contains appreciable molybdenum and a spot test for this may help in cases of doubt. The 7% chrome steel is readily distinguished from the 9% chrome steel by a relatively quick reaction to a brown solution; the 9% chrome steel does not so colour within the prescribed time, the solution, when reaction occurs at all, remaining grey.

Solution 5

Phosphoric Acid (H_3PO_4–85%) ..	12½ parts
Concentrated Nitric Acid	10 parts
Concentrated Hydrochloric Acid ..	4 parts
Distilled Water	10 parts

The solution should be aged for a few days before standardising against identified samples of the materials it is to be used for distinguishing. It is preferable to make up a stock solution from which the test solution in the dropping bottle may be replenished or replaced from time to time. This solution should be checked weekly against the standard samples.

Solution 5 is used at two stages in the procedure; in conjunction with Solution 6 (see column 6 of the table) and by itself (see last column). The reaction with Solution 6 will be described in the notes under that heading. When used on its own in the last stage of the procedure, one drop of the solution is applied to a freshly prepared surface and the reaction observed. The test differentiates between the different types of austenitic steels by the times taken to reach a state of passivity. This is indicated by a fairly abrupt cessation of effervescence which leaves a clear green solution, the depth of colour depending of course on the time of reaction. The degree and manner of differentiation obtained between members of this group of steels is controlled by the adjustment of the solution and can consequently be varied to suit the user's circumstances. The times given in the table are merely typical of what can be obtained. As first made up and aged the solution will probably require adjustment. It is checked against standard samples of the austenitic steels with which the user is concerned, and if the times of reaction are too close together for reliable differentiation, adjustment is necessary. A few drops of hydrochloric and/or phosphoric acid usually suffice. In general, the addition of nitric acid speeds up the attainment of passivity, hydrochloric acid has the reverse effect and phosphoric acid tends to prolong the reaction with the lower alloy materials but has little effect with the more highly alloyed ones.

Solution 6

Phosphoric Acid (H_3PO_4–85%) ..	2 parts
Concentrated Nitric Acid	4 parts
Concentrated Hydrochloric Acid ..	1 part
Distilled Water	2 parts

This solution also should be aged for a few days before standardising against identified samples of the materials it is to be used for distinguishing. Similar remarks apply to the use and adjustment of this solution as were applied to Solution 5. In practice it will be found to require much less attention.

Solution 6 is used at two stages in the procedure: in conjunction with Solution 5 for distinguishing between 12 and 18% chrome and higher chrome steels, and by itself for distinguishing between 12% and 18% chrome steels. Other alloy materials must, of course, have been eliminated by earlier steps in the procedure.

In the first mentioned case, the solutions are used by adding to a freshly prepared surface, two drops of Solution 5 and one drop of Solution 6. The reaction is observed for two minutes. With 25% chrome steel the reaction will cease within two minutes to give a clear green solution whilst 12–18% chrome steels will react until the acid is spent.

To distinguish between 12% and 18% chrome steels, Solution 6 is used on its own; one drop of the solution being applied to a freshly prepared surface. With a 12% chrome steel the reaction continues until the acid is spent, whereas with an 18% chrome steel it ceases within a minute, leaving a clear green solution. 18%Cr–2%Ni steel of the EN.57 type can be distinguished from the straight 18% chrome steel by applying a spot test for nickel (see Appendix).

Solution 7

Concentrated Hydrochloric Acid

To use the test, apply one drop of the solution to a fresh surface and observe for one minute. A reaction and colour, with Solution 7 alone, identifies chromium or Stellite in the manner indicated in the table. If there is slight or no reaction, and no colour, add to the spot of solution on the alloy one drop of Solution 8.

Solution 8

10% Potassium Ferricyanide Solution

The colour which develops when this solution is added to the spot of acid on the alloy distinguishes whether it is ferrous or non-ferrous and so determines subsequent procedure (see Notes G and H). With this hydrochloric acid—ferricyanide test, absolute cleanliness is particularly essential as any contamination by ferrous material from a dirty file or emery paper will cause a non-ferrous metal or alloy to be returned as ferrous.

Procedure

The manner in which the test solutions are used has been described above. The order in which they are used is given in the table. This order of testing must always be observed as it will be obvious from an examination of the table that the successful use of the later solutions depends upon the lower alloy materials having been eliminated. For example, Solution 5 will not distinguish between 18 : 8 stainless steel and lower alloy steels and Solutions 1 and 3 must have been used for eliminating the latter before there can be any distinguishing between 18 : 8 and other high alloy steels. Similarly, it is the results of using Solutions 1, 2, 3 and 4 which allow of distinguishing between 5% chrome steel and lower and higher alloy materials. The results of the earlier tests also indicate, of course, which of the later solutions are to be applied. There will be times when the condition of the material limits the possibilities, and certain steps in the procedure may then be omitted.

The reactions described apply to tests conducted on metal in the temperature range 50° F.–90° F. At other temperatures, reactions will be appreciably slower or faster and tests should be standardised for the prevailing conditions.

Notes for Use with Table

In order to keep the table as simple as possible, the final separation of some materials has been covered in the notes below (which should be read in conjunction with the table).

Note A.—The low alloy steels in this group can be distinguished by the application of spot tests specifically for nickel, chromium and molybdenum (see Appendix) and by hardness testing. Sometimes, a nominally '5% chrome' steel may fall in this group (if the chrome is

MATERIAL IDENTIFICATION SPOT TESTING SCHEME.

	Solution 1.	Solution 2.	Solution 3.	Solution 4.	Solution 5 & 6	Solution 6.	Solution 7.	Solution 7 & 8	Solution 5.
Carbon Steels Low Alloy Steels	Reaction to dark coloured spot	N.A.	Copper deposited (see note A)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Ordinary or Low Alloy Cast Iron 12% Manganese Steel			No copper deposited (see note B)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Cupro-Nickel Hastelloy A (Cast) Hastelloy B Monel	Reaction to green solution (see note C)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Hastelloy A (Wrought) Nickel	No effervescence but stain develops (see note D)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Ni-Resist Cast Iron 5% Cr. ½% Mo. Steel	No reaction or stain (see note F)	Copper deposited (see note E)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
7% Cr. ½% Mo. Steel		No copper deposited	Copper deposited	Strong reaction to brown solution	N.A.	N.A.	N.A.	N.A.	N.A.
9% Cr. 1% Mo. Steel				Slow reaction and grey stain only	N.A.	N.A.	N.A.	N.A.	N.A.
12% Chrome Steel				No reaction or stain	Continuing reaction	Continuing reaction	N.A.	N.A.	N.A.
18% Chrome Steel 18-2% Cr. Ni. Steel						Reaction ceases within 1 min. to give clear green solution	N.A.	N.A.	N.A.
25% Chrome Steel					Reaction ceases within 2 min. to give clear green solution	N.A.	N.A.	N.A.	N.A.
Chromium			No copper deposited	N.A.	N.A.	N.A.	Reaction to pale green colour	N.A.	N.A.
Stellite							Very slight reaction. Pale blue colour	N.A.	N.A.
Nickel Hastelloy C Hastelloy D							Slight or no reaction. No colour	Yellow or brown colour (see note G)	N.A.
Duriron								Blue or bluish green colour (see note H)	N.A.
18-8 Cr Ni. Steel									Reaction proceeds beyond 4 min.
18-10-2 Cr. Ni. Mo. Steel 25-12 Cr. Ni. Steel									Reaction ceases in 2–3 min. to give clear green solution (see note J)
18-10-3 Cr. Ni. Mo. Steel									Reaction ceases in 1–2 min. to give clear green solution
25-20 Cr. Ni. Steel									Reaction ceases within 30 sec.

N.A. Signifies Test not Applied.

below about $4\frac{1}{2}\%$ there will be a reaction with Solution 1) but on applying the spot test for chromium will be distinguished by the deep violet colour developed. As $2\frac{1}{2}\%$ chrome steel develops a similar colour, quantitative analysis would then be necessary to separate the two possibilities.

Note B.—12% manganese steel is non-magnetic, or only slightly magnetic, and can be distinguished from the cast irons by this property. Hardened steel may be found in this group but can be distinguished by hardness and spark testing.

Note C.—Allow the nitric acid solution to remain on the specimen for two minutes and then lightly rinse with water. A dark bluish coating on the alloy indicates *Hastelloy B*. If the surface of the sample is only etched, with no coating, apply to a fresh surface one drop of water and two drops of 1 : 1 nitric acid (Solution 1) and observe for two minutes. No reaction indicates *Monel*, a pale green solution, *Cupro-Nickel*, and a green solution with a dark blue ring round the spot, *Hastelloy A* in cast form.

Note D.—The stain or etch on the metal surface will show clearly when the drop of acid is rinsed away. To separate *Nickel* from *Hastelloy A* apply to a fresh surface one drop of Solution 15 (see below). An immediate reaction to a yellow solution indicates *Hastelloy A*. No reaction indicates *Nickel*.

Note E.—*Ni-Resist* can be distinguished from 5% chrome by applying the spot test for nickel (see Appendix). It is also non-magnetic.

Note F.—No reaction with Solution 1 indicates this range of materials but also lower alloy steels which have been calorised. If this surface treatment is suspected it will be necessary to remove about 0·025 in. and retest.

Note G.—Add to a fresh surface one drop of Solution 15 and observe after two minutes. A reaction and grey stain indicates *Hastelloy D*. If there is no reaction or stain with this solution, apply to a fresh surface one drop of concentrated nitric acid and observe after two minutes. Slight attack and a pale green solution (tilt drop to improve visibility) indicates *Nickel*. No reaction indicates *Hastelloy C* (similar passivity will be exhibited by other chromium-containing alloys which, to be in this group, will be non-ferrous).

Note H.—Apply the nickel spot test procedure (see Appendix) to distinguish between *Durircn* and the high nickel corrosion and heat resisting steels. Differentiate between the latter with Solution 5.

Note J.—18 : 10 : 2 stainless steel is appreciably magnetic (as, of course, is 18 : 10 : 3) and can be distinguished from 25 : 12 by that property. The American variants of the above molybdenum-bearing stainless steels are higher in nickel content and, in consequence, are almost entirely austenitic. In this case they cannot be identified by their response to a magnet and must be distinguished by applying the spot test for molybdenum.

APPENDIX

Specific Spot Tests for Nickel, Chromium and Molybdenum

Many readers will be familiar with the spot tests which are used for detecting the presence of certain alloying elements, but the following are three which the writer has found useful. That for chromium appeared in *Metal Progress* for December, 1942 (W. O. Philbrook—" Spot Test for Chromium ")'

The solutions required, apart from those already mentioned, are as follows :—

Solution 9

Dimethyl glyoxime	1 g.
Ammonium Acetate	10 g.
Ammonium Hydroxide	30 ml.
Glacial Acetic Acid	60 ml.

Solution 10

Phosphoric Acid (H_3PO_4–85%) ..	5 ml.
Concentrated Nitric Acid	20 ml.
Distilled Water	25 ml.

Solution 11

Bromine	2·5 ml.
Sodium Hydroxide	20 g.
Distilled Water	400 ml.

This solution will require to be replaced at intervals. Its life may be prolonged by the occasional addition of a few drops of bromine.

Solution 12

Concentrated Sulphuric Acid	5 ml.
Distilled Water	25 ml.

Solution 13

Phenol (cryst.)	5 g.
Glacial Acetic Acid	50 ml.

Solution 14

S-Diphenyl Carbazide	0·1 g.
Glacial Acetic Acid	5 ml.
Ethyl Alcohol .. .. to	50 ml.

Dissolve the carbazide in the glacial acetic acid and dilute to 50 ml. with ethyl alcohol. The solution should be replaced when strongly coloured and should be kept in an amber glass bottle.

Solution 15

Concentrated Nitric Acid	20 ml.
Concentrated Hydrochloric Acid ..	20 ml.
Distilled Water	20 ml.

Solution 16

Sodium Hydroxide	15 g.
Distilled Water	50 ml.

Solution 17

Concentrated Sulphuric Acid ..	25 ml.
Distilled Water	25 ml.

Solution 18

Potassium Ethyl Xanthate	1 g.
Distilled Water	50 ml.

Procedure

Nickel.—To a prepared surface, add one drop of Solution 4 (for low alloy materials) *or* one drop of Solution 5 (for high alloy materials) and allow to react for about 20 secs. Absorb the resulting solution in a piece of filter paper. Remove the filter paper and add to it one drop of Solution 9. A pink colour will develop if nickel is present in the alloy ; faint pink if less than 1% is present ; bright pink for high nickel contents.

Chromium.—To a prepared surface, add one drop of dissolving acid (Solution 10) and allow to react for 20/30 secs. Touch the flat end of a glass rod to the surface of the steel under the acid and transfer the solution adhering to the rod into the hollow of a white porcelain

spot plate into which two drops of Solution 11 have already been added. Stir. Add one drop of Solution 12 and stir again. The reddish brown precipitate should re-dissolve to give a clear yellow solution. (If the precipitate or solution is greenish, the first reaction has been allowed to proceed too far or Solution 11 is spent. If this is the case, the fault should be rectified and the test re-commenced). Add a drop of solution 13, and a colourless solution should result. Now add one spot of indicator (Solution 14). Low chrome (below 1%) will give a pale pink colouration. The colour deepens with increasing chrome to a deep violet colour. The high chrome steels (above about 5%) will not react with the dissolving acid but steps in the general procedure will identify these.

Molybdenum.—To a prepared surface, add one drop of Solution 15 and allow to react nearly to completion. Add one drop of Solution 16 and stir with a glass rod. Add one drop of Solution 17 and again stir (the precipitate should just re-dissolve). Apply a piece of Postlip 633A filter paper over the spot and add to the moistened area two more drops of Solution 17. When this is absorbed, add 2 drops of Solution 18 (indicator). After a few seconds if molybdenum is present a pink colour will develop in the acidified area and in the fringe of contact between the wet paper and the specimen. The limit of detectability with fresh solutions is about 0·1% Mo. This gives the faintest pink colour; higher molybdenum contents give increasing colour intensity up to a brick red colour. Plain carbon steel gives a brown coloration only.

N.B. The chromium and molybdenum spot tests should be checked against a suitable standard (e.g. EN 19 or EN 110) once a week.

Information—The Springboard of Productivity

INCREASED productivity is too often thought of only in terms of mechanisation and the better use of manpower, of developments in scientific research which will result in more rapid processing, or the more economical use of materials. These are the end-points of any attempts to increase productivity. Before these goals can be achieved much research must be undertaken—the "know-how," as many Anglo-American Productivity Team Reports have stressed, is vitally important. Know-how implies a search for information on the methods used by others in industry and research anywhere in the world. With the increasing tempo of scientific and industrial research in recent years there has been a vast increase in the volume of literature in all fields. In this maze of books, periodicals and reports the industrialist and research worker must find the answers to their problems.

If the searching of this literature can be speeded up so then will be the application of research and the achievement of higher productivity. This searching of scientific and technical literature is a highly skilled technique with a sound scientific basis, and has led to a phenomenal increase in special libraries and information services. Even so, there are still many organisations which have not established them, or which require to develop them further.

In 1947 this matter was considered by the Government Committee on Industrial Productivity. The terms of reference of the Committee's Technical Information Services Panel were to review existing information services for distributing scientific and technical information and to consider what improvements could be made to ensure a rapid and wide dissemination of such information to industry.

One important development has been the provision of a Treasury grant, administered by the Department of Scientific and Industrial Research, to Aslib (formerly the Association of Special Libraries and Information Bureau) for setting up a Consultant Service. Aslib has already made a notable contribution to information services, and this development should do much to increase the use made of new knowledge. The Consultant Service will draw upon Aslib's existing resources, extended by further research into, and development of, information techniques, making these available both by advising those organisations which need to establish internal information departments and by assisting the development of those already in existence.

Details of the Consultant Service and other facilities provided by Aslib can be obtained from the Director, Aslib, 4, Palace Gate, London, W.8. Telephone: Western 6321/3.

International Council for Electro-Deposition

THE Institute of Metal Finishing, in conjunction with the American Electroplaters' Society, announces the formation of the International Council for Electrodeposition.

The object of the Council is to initiate and co-ordinate all activities of member Societies where international action is necessary or desirable. Such activities may include the holding of international functions, questions of nomenclature and terminology, and the representation of the interests of electrodeposition on international bodies.

Representation on the Council is initially confined to the Institute of Metal Finishing and the American Electroplaters' Society. Membership of the Council is, however, open to any Society, one of whose main interests is the subject of electrodeposition.

The headquarters of the International Council are 27, Islington High Street, London, N.1.,

Symposium on Diamond Drilling

THE Council of the Chemical, Metallurgical and Mining Society of South Africa announces that, as a result of a suggestion made by the Diamond Research Laboratory, Johannesburg, a symposium on diamond drilling has been arranged, and will be held in Johannesburg, 21st–23rd April, 1952. Following the three days of technical sessions, tours will be arranged by the Diamond Research Laboratory to the diamond drilling operations in the gold and diamond mines of South Africa and in the copper properties of Northern Rhodesia.

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